JAEA Knowledge Management Review 2008

Foreword

This note contains the records of two separate workshops organised by JAEA on topics related to the Knowledge Management (KM) project. For both of these, the aim was to present the background, plan and current status of KM, with the focus on specific key applications. The first workshop examined the complex process of site characterisation and “geosynthesis”, while the second considered development of advanced repository concepts and the “next generation” performance assessment codes and databases needed to support them.

Despite some differences in the attendees, overlaps in areas covered make it sensible to couple these two workshop records. The agendas, participant lists, a questionnaire distributed in advance and the presentations made are also appended.

Workshop to review the progress of development of a Knowledge Management System (KMS) and an integrated Information Synthesis and Interpretation System (ISIS)

11th to 12th November 2008

This record documents discussions during the review workshop. The information follows the sequence of presentations during the workshop and reflects the main questions and comments generated by each presentation. Comments are not assigned to individual reviewers.

Day 1

First presentation: The JAEA KMS – why and what? (H. Umeki)

Questions and discussion

The overall reaction to the KMS was that it is at the forefront of development in the field and that, while it is ambitious, the need for such a system is clear. The theoretical arguments in favour of developing such systems are effectively exhausted at this stage and JAEA was complimented on taking the lead in developing such a system within the context of radwaste management.

Tacit knowledge

It was generally agreed that implicit (tacit) knowledge is a concern and the need to 'externalise' this knowledge, which is mainly in the heads of experts, is important. There is also a problem in that older experts in radwaste programs (as in many other fields) are less IT literate than the younger generation. The solution to eliciting tacit knowledge needs to combine advanced and conventional methods (e.g. expert interviews and IT-based approaches). The KMS has to support fostering of experts and JAEA is focusing on minimising loss of knowledge using expert systems to capture knowledge, but this can never be 100%. It should also be borne in mind that not all knowledge will be of use. Regarding interviewing of experts to extract knowledge, this is a trial and error process, but JAEA has developed a fairly sound approach in the area of geosynthesis. This needs to be extended and formalised.

There are many ways of capturing/preserving knowledge. For example, older staff can be brought in to teach in training courses. Young staff can be brought into complex projects, such as natural analogues, where mentoring can be used. Young staff should be allowed to make mistakes – this is part of learning. JAEA is open to all possible methods of capturing knowledge (e-learning, work at URLs, etc.).

There were efforts as long as 20 years ago to develop expert systems but this did not prove successful. It is very difficult to extract knowledge from experts unless they see the benefit of passing on their know-how.

It was often the case in such early projects that the approach was to extract knowledge using knowledge engineers who in fact knew nothing of the area in which they had to extract the knowledge. A better approach when eliciting knowledge in the area of geology, for example, is to use a geologist who has learned to use IT to extract knowledge. The message is not to use knowledge engineers in such situations, but to use generalists who learn IT to extract information. It should be also noted that modern IT has many advanced tools available for extracting knowledge, which could be used here.

Specialists/generalists and meta-knowledge

Meta-knowledge is in the heads of generalists who have a wide overview of projects gained from any years experience in radwaste programmes. Programmes need both experts and generalists, but what is being lost as senior staff retire is the overarching overview needed to put issues in context.

The paradigm shift in the radwaste field

While the KMS presented represents a huge challenge, there seemed to be a contradiction in saying that it represents a paradigm shift and, at the same time, confirming that the system would use existing technology without new software development.

The point is that JAEA is not focusing on advanced software tools but on dynamic systems to manage knowledge. The system will be user-driven and not IT-driven. The paradigm shift has to be for radwaste organisations and not for knowledge engineers. Radwaste people are inexperienced in knowledge management and there has been no real change in how things are done / how knowledge is treated for centuries (libraries, archives, etc. are still the main way of "managing" information/knowledge). However, traditional techniques will break down and there has to be a change in the conservative approach of radwaste organisations. This is effectively a cultural change and will be difficult to realise. Unless the advantages of such a system can be communicated, all the IT tools in the world will not help.

Information and knowledge

A distinction is generally drawn between information and knowledge but the definitions of these terms are not entirely clear. One approach is to say that information is basic to knowledge and is required to create knowledge. While information is merely data in context, knowledge differs in that it is predictive and can be used to guide action. These deliberations aside, the main challenge is to create an environment in which knowledge can be created and disseminated. This is perhaps the paradigm shift required. The issue is how to present information in such a way that people can take it and make use of it. People need to be "knowledgeable" and an environment has to be created for this to happen. Bringing together information management and people with experience will create knowledge. Accessibility is critical. The system has to be attractive to all users. It is important to structure knowledge hierarchically depending on user requirements.

Setting up an information management system is relatively easy – what is difficult is making people change the way they work. Why should an expert share his knowledge? What's in it for him? People tend to look for the benefits they will have from a particular action and these are not so clear in the case of knowledge dissemination. The paradigm shift is getting people to share and providing incentives to pass on knowledge. We are still a long way from achieving such an open working environment.

Second presentation: Design and development of the KMS, with the emphasis on geosynthesis (K. Hioki)

Real-time systems

It is clear that the KMS is used to synthesise and manage existing knowledge. The example of the expert system used in borehole drilling is a real time application and it was not clear why such an ambitious approach was being developed. This work was put in context by explaining the intention behind it, i.e. that it will run in parallel with existing systems by way of a back-up. Using such an expert system, which includes a logging function, will also provide a continuously expanding case base on how experience is used to make decisions.

The reality is that the implementer (NUMO) could have 3 or 4 investigation sites running parallel and the experience for this does not exist in Japan (also the case for many other countries). The KMS will complement conventional systems by providing IT support. It is not the intention to replace experienced drilling teams.

JAEA has drilling experience (e.g. in URLs) and the question is how to pass this experience on to NUMO for real-time application. What is important is to create a framework for passing on such experience/knowledge.

Delivery of ISIS to NUMO is foreseen for 2012. It will be integrated into the KMS and continue to be further developed. Creating this system has been identified as a goal but it will not replace the experienced human element (e.g. drill master). What the system provides is case experience as support. As the system evolves and becomes more useful with time, it is hoped that drilling teams will derive something from it.

Feedback loops

The issue is not just about providing information but of modifying expectations. The model shown does not make it clear that feedback is presently internal. It has to feedback into the primary input data in order to change expectations from the beginning – this is when an expert system provides payback. The issue is what the system can help us to do better and what it can change about the way we do things.

Third presentation: ISIS: concept and approach (H. Osawa)

General comment

The latter part of the presentation is an example of how to overcome the knowledge acquisition bottleneck; a way of acquiring and making more widely available knowledge from highly experienced specialists and generalists. Normally there are experts on the one hand and knowledge engineers on the other, which creates an interface problem. The system illustrated is an attempt to overcome this situation.

Conflict and contradiction

Systems will almost always contain conflicts and contradictions (e.g. if you want 4 opinions ask 3 geologists) and a key issue is how to balance these. The solutions at the end will not be simple black and white solutions but will represent a spectrum of output. This is part of having real knowledge of a real system. Requirements go in at one end and possible output at the other and are iterated to find a compromise.

A range of experts will be interviewed to acquire expert knowledge and the hope is for convergence or consensus. However, this is very difficult in a complex area such as geosynthesis (easier for e.g. the EBS). This also relates to the issue of hybrid systems. Not all tasks can be automated and the level of automation has to be appropriate.

In the NUMO argumentation network, for example, conflicting requirements will pull the programme in different directions. It is important to make it easy for top decision-makers to see all the input needed to make a decision. It is important to ensure that the decision-makers have the whole picture; this should make decision-making more transparent.

Black-box situations should be eliminated. It should be clear why decisions were made. For example, why was the KBS-3 concept adopted? Very few people can answer this now. Although there were good reasons for some design choices at the time, these may be less applicable now.

Redox decision/hydrogeochemical synthesis

The question here was how to derive a conceptual understanding of chemistry from raw data. It is important to formally define the steps for getting to this understanding, which will differ from site to site.

Hydrogeochemical synthesis involves structural geologists, hydrogeologists, mineralogists, etc. Knowledge needs to be structured to provide an approach tailored to different sites. Argumentation models can be developed, which can be tested for relevance to particular sites in order to tailor the process. Experts are interviewed based on this structured system of argumentation, to determine what information they are using and how they are applying it.

JESS and Protégé

Apart from a better explanation of acronyms being needed, it was not entirely clear what the functions of Protégé and JESS were.

They are combined to make an expert system, but they only provide a programming environment – extracting expert knowledge is still the work of other people (e.g. by interview, etc.). The computer will never make a decision – it can only present the information needed for humans to make decisions. It is necessary to talk to experts to learn how to extract knowledge. Once an expert system is developed, it will represent decisions by other experts if it is any good.

The challenge is to encourage experts to make their own rule base. The expert system should not force one single answer, but a range of possibilities.

Fourth presentation: ISIS: design and development (T. Semba)

It was stressed that this system is only a preliminary version of a prototype. The importance of using existing software and tailoring it was highlighted – there is no high technology development involved.

Blackboard system

It was not entirely clear where the human element comes in on the blackboard with the mother and children and what the exact function of the blackboard is. Human experts will still be needed in the future. The focus here is on modules where the expert system provides support. Information is integrated and made completely accessible – the system is more of a communication interface than anything else. It provides a snapshot – in real life, moving through the modules to the output at the end could take weeks or months. The blackboard is shared working memory. The mother (the control shell) knows the right person (a child, i.e. knowledge source) to perform a task and can alert him (/her) to do so.

It is hoped that, eventually, the system will be able to include, for example, budgeting considerations, socio-economic factors, etc. The system is hybrid so it is not a case of "all or nothing". It would be possible to expand the system and to use the blackboard to alert the appropriate person(s) to consider e.g. budgeting factors, socio-economic factors.

Clarity

For the expert system, clarity is needed at all times; it should not be a black-box. This is particularly important when justifying decisions to non-experts. The aim is to generate confidence that we are making the right decisions and it is necessary to know the limitations of the tool and the output, attach caveats, etc. Validation of results is important.

Sustainability

The lifetime for such expert systems that are used to decide on site suitability was not clear. The tools are sustainable over longer times but will need to be modified in the future to remain state of the art and to ensure that people continue to use them.

The aim for the KMS is to build up modules accumulating case understanding. Case knowledge is in the heads of the experts but it is important to build up systems that capture this knowledge as quickly as possible. On a 100 year perspective, case experience should have been built up, but some individual components may have a short shelf life, for example Eh. If this were no longer used in the future, it would be necessary to justify why (change management). Why changes are made is not well documented at present, meaning that things tend to be reinvented in cycles with no clear understanding of why. If something is properly recorded, it makes it easier to decide whether it should be repeated / revived in the future.

System users

This is effectively a tool to be used by experts and non-experts will not use it to make decisions. However, an expert in one area might try something completely outside his field using such a system (i.e. in an area where he is not an expert). There are not enough experts to go round and this is where the system can help. The possibility of developing a more educational version should be considered.

There are two aspects to the system: 1) assistance of experts; 2) communication among experts. It helps to balance needs – if, for example, a driller can explain why he wants to use organics and a chemist can explain his problem with this, a balance can be reached. There will often be conflicts and a need for compromises and trade-offs, but the system can help to balance needs and to find solutions through communication.

A non-expert should be able to go into the system and see why/how decisions are made. Openness and transparency are important, particularly with a volunteering approach.

Safety function

Safety functions are indicators of relevance to the overall argument of safety: although very useful conceptually, they are tricky to define and apply in real systems. In the future it is intended to better identify safety functions that are key to the safety case. This might usefully be developed in an argumentation network.

In Sweden for example there is a defined EBS and safety functions have been defined. For NUMO, nothing has been defined on safety functions as no site has so far been volunteered. There are many possible combinations of safety factors. This was approached in the past using expert judgement. NUMO will have to explain its choices rigorously.

At the interface of disciplines, a communication protocol should be used to identify what information has to be passed from whom to whom. Safety function indicators are an aspect of this, which complement other, more basic EBS- and geo-indicators.

Day 2

Structured discussion session 12/11/2008

The discussions were structured around a questionnaire that had been distributed to participants.

Proceedings began with reactions by key system users to the KMS and ISIS presented on the previous day.

Implementer

Overall, the KMS was considered to be a practical system on which NUMO could rely.

Potential difficulties in applying the KMS were identified as follows:

- Who uses the expert system? For example, is it usable by specialists with little geology background?
- When should NUMO start using it? At the beginning of preliminary investigations (PI)/detailed investigations (DI)?
- How can NUMO use the system effectively?
- Can the system support top decisions? It must be consistent throughout the whole site selection process.

The KMS must:

- Be easy to apply and maintain.
- Be simple to customise. One concern is that staff may misunderstand the need for customisation.
- Include unsuccessful stories/failures. During DI, there will be problems and surprises. The system should not be overly optimistic.
- Be suitable for training new staff (KMS as an education/training tool).

For the geosynthesis, one question was who will use the system and when. It can be used (1) to determine investigation methods and (2) after some investigations to develop plans for further investigations and is actually useful for these tasks. Nevertheless, we have to think about information relevant to a certain “box” in the JAEA Geosynthesis Data Flow Diagram together with that relevant to far away "linked boxes", which requires an overview of the background and boundary conditions considered.

Regulator

The application of the KMS in making the safety case (SC) /site investigations is clear, but the KMS is also important for the regulator, who needs integrated knowledge to evaluate the case made by the implementer. The role of the KMS with respect to regulatory guidelines is important and it should include aspects to support formulation of criteria and guidelines and quality assurance. From this point of view, knowledge/information including international experience relevant to issues such as the timeframe and safety indicators should also be scoped in the KMS.

Making the SC and KMS development has to be iterative; once through is not enough. In terms of safety guidelines and fundamentals, many considerations are 20 years old and iteration of the SC and KMS is very important for correcting past experience. The system should facilitate two-way communication between users and knowledge providers in making the safety case.

The scope of knowledge focused on by the regulator is relatively narrow, i.e. on strictly safety-relevant issues to be "regulated". How to apply the KMS to the narrower viewpoint of the regulator is an issue.

The knowledge base and the argumentation models impose a structure on the SC, making it easier for the regulator to identify key issues and reach decisions.

Education and failure stories have to go into the KMS. The case history of past problems needs to be maintained and extended. When interviewing experts it is necessary to ask what went wrong but this is not easy to elicit.

Academia

The general impression was that the KMS would be challenging to use as the university system is very different and it will not be easy to encourage students to apply such a system. The question is how to use a KMS to develop new ideas, which is what much of the research at a university is about. The KMS could be applied to cultivate new research ideas. The argumentation network can be used to identify gaps in knowledge, which will be challenging areas for research.

Failure examples may help to identify gaps in knowledge and generate new ideas/solutions.

Questions were also raised regarding maintaining the system after completing a project and regarding funding and keeping the system up to date.

Structured discussion

KMS goals

Are the project goals clear? Are they adequately justified? Is the effort invested appropriate to requirements?

Comments are presented in the sequence in which they were made.

The general agreement was that the goals are clear and justified and the need for the KMS is not in question. What is not entirely clear is who will actually use it (performance assessor, implementer?). Each person will use the KMS differently. At the moment the concept of the KMS is fairly general and it needs to be stepped up to become more user-oriented. It was also not fully agreed how the system can be used for teaching. The aspect of communicating with users is crucial.

The term KMS and what it actually comprises needs clarification. The central component is the knowledge base (KB) and not an expert system. The main aim is to improve handling and storage of information and the KB should be accessible to everyone. Smart search engines are a key technology in this regard. This is one aspect – the other aspect is toolkits such as ISIS, which is clearly aimed at geologists. Tools will be tailored for users and input from users is needed for this. The focus is not just on safety assessment –all the constraints on the programme have to be borne in mind.

The chicken and egg argument – is KM a solution looking for a problem? There has been discussion of the age bulge, loss of expert knowledge and the role of expert systems, but the discussion is lacking in overall context and an explanation of what the real drivers behind the development are (e.g. a government directive that justifies this work). How will the KMS link into the universities and attract new blood into the industry? The strategy side is not clear as the move from the KMS into expert systems such as ISIS was relatively rapid. It is important to note that the KMS is not just an expert system.

The starting-block is JAEA’s H17 report, where KM was identified as a need and JAEA was assigned responsibility for developing a system. A survey of the state of the art was carried out (although extending this with smart search engines still needs to be considered).

Libraries and archives are no longer sufficient and this has to be accepted and the claim clearly demonstrated/justified. There has to be a change of attitude in the organisations that would use a KMS. Prototypes need to be demonstrated to change fundamental thinking. The next step will be to carry out case studies.

The KMS and its advantages have to be explained and this is difficult. The approach has to be stepwise but what are the steps? What goals have to be prioritised? A clearer picture is needed for further development.

Any one of the justifications mentioned in the presentations for developing this system would be enough (no-brainer). It has to be done and the earlier you start the better. It is needed even for QA purposes alone. The ISIS expert system is not so convincing (clicking buttons to get answers). It is important not to wait for new tools but to customise what you already have. Building the KB could take years.

Summary

- Generally agreed that goals are clear and justified and the need for KMS is clear, although the development is ambitious and challenging.
- Less clear who will actually use the KMS. Need to communicate with users to identify needs – step up from general to user-oriented.
- Not clear how KMS would apply in teaching/cultivating ideas.
- Lack of context (longer timescale and bigger picture) and what the drivers are.
- The KMS is not just an ES. Make overall strategy clearer.
- Need to start now. Waiting for new tools is not an option – customise what is available but be flexible. Need user input to tailor the tools.

- Need to maintain flexibility and possibility for creativity – do not constrain users.
- Need to clarify what KMS comprises? Main component is KB with all knowledge readily available and accessible (coupling advanced communication tools with smart search engines). The other aspect is toolkits such as ISIS.

KMS approaches

Are the approaches adopted reasonable? Is the level of work representative of the state of the art? Do the chances of reaching a successful output seem sufficiently high?

The stepwise approach is very important. A clearer picture is needed of overall strategy. So far, development of the system has been guessing at user needs. Now real joint case studies are needed with external users such as the implementer and regulator.

The question is raised of the success of the output, but what is the output? Is it a function of funding and time? Past efforts at ES development often collapsed, but many of these attempts started from scratch and were IT-driven. The JAEA approach is different. It is not starting from scratch and it will be user-driven.

How is knowledge extracted from the system/KB? Experts themselves might not know how to do this. What are needed are teams of knowledge engineers and experts who can bring IT to radwaste management. The teams need to amalgamate and be prepared to step into each others' fields.

What has been presented may fail as an expert system; the expert system is only a small part of the whole. The KMS should not be sold as an ES and maybe the real-time system is not the point. The tools should aid and support people. Continually putting knowledge into the system is what makes for successful output.

In terms of feedback loops, processes need to be examined critically. Going back to the beginning and changing how things are done (primary feedback) is important for further modifying processes and managing creativity.

Summary

- Stepwise approach is important. Clearer picture of overall strategy is needed.
- What is the intended output – needs to be defined.
- JAEA approach is not IT-driven, and not starting from scratch. Approached from what users want/what experts can do lead to less chance of failure.
- Need for teams of knowledge engineers and experts who step into each others areas.
- Selling the system just as an ES may fail. ES is only a small part of the KMS.
- Real-time tool: less clear if this is the correct/justified approach. Tool should act as an aid – inputting information into the system to generate successful output.
- Feedback loops – going back to the beginning to provide input and changing how things are done. This is the payback of KMS.

Output

Have the results to date been clearly presented? Are interpretations and conclusions well supported? Do proposals for future work seem reasonable?

There is a need for more clear formulation – it would help if knowledge engineers could define their tools in a way that users can understand them and feel confident about using them. The system should always be user-oriented in order for users to see what works for them and to “buy in”.

The aspect of communication is important. A matrix or menu could be used to show what tools there are, how they can be applied and where they have been tried. The structure needs to be improved. Priorities should be set to define the effort needed.

If H22, which is a JAEA mandate, is a conventional report, the need for a KMS is lower. If the Coolrep approach (see later) is used, this is a good platform for application of KMS and makes motivation higher. The tools could be integrated into Coolrep.

Summary

- Need for knowledge engineers to define/describe their tools to provide users with a better understanding of how to apply them.
- KMS needs to be user-oriented – allows users to see what works for them. Encourages buy-in.
- Importance of communication. Idea of having a matrix/menu with what tools are, how they can be applied and where they have been tried.
- Coolrep: If H22 was a conventional document, need for KMS less. The Coolrep concept – a good area for KMS application – provides higher motivation. Tools could be integrated into Coolrep.

Improvements

Are there ways in which the project could be improved in terms of organisation, programme of work, priorities and technology used?

This is effectively covered in other parts of the discussion.

Collaboration

Are there any areas where collaboration with other organisations would be beneficial? With organisations in Japan? Organisations in other countries? International or multinational organisations?

Up till now development of the KMS has generally been closed and there is now a need to identify the users and their requirements. Within the Japanese programme, it is essential to work with potential external users of the system.

There could be general collaboration in specific areas, e.g. expert elicitation, which is an area of concern for most programmes. International organisations could make an inventory of experts.

Developing countries such as Korea and Taiwan may be a good area for collaboration. They have knowledge but not much experience. Expert systems could be used to transfer experience or provide training support.

The existence of the IAEA Knowledge Management Unit focusing on the tools and techniques for the nuclear industry was mentioned. It would be useful for JAEA to make contact with the Unit.

There may also be possibilities in the oil industry.

Summary

- Development to date has generally been JAEA-internal – need now to more actively define and communicate with external users.
- Collaboration could be general or on specific topics (e.g. elicitation of tacit knowledge).
- Interest from developing countries (example of JAEA already using KMS with Korea for technology transfer purposes).
- IAEA Knowledge Management Unit would be a useful contact.
- Another possibility is the oil industry.

ISIS goals

Are the project goals clear? Adequately justified? Is the effort invested appropriate to requirements?

The real-time approach is very ambitious but, where there is a short time frame for making decisions, a quick response system can be useful. Its limitations must, however, be clear. The blackboard can be used to bring together the people involved in a site characterisation to optimise communication.

Will ISIS eventually be a real-time system for all aspects of site characterisation? What is it intended to achieve? The aim is to integrate all material obtained in site characterisation and continually feed it into the system. The objective is to link all aspects of the field programme and to provide an integrated database for all users to facilitate communication. It is important not to look just at the geo-links but also at other (e.g. safety) aspects.

The system should ideally be available to NUMO from as early as the literature survey phase. The aim is to deliver a working system within around two years. The boundaries need to be defined and participation of users is critical from now on.

As the programme advances, more modules can be built in. The goal of the toolkit component is to provide optimum KM support to users based on their requirements. As a toolkit, ISIS should be continually evolving. As a working environment, the expert system is a unified way of expediting communication and collaboration among stakeholders. Using the system in this way is feasible now.

Using the flow system backwards starting from the output may be instructive. Information should not be collected simply for the sake of it (geophilately), but should be need-driven. The question to be asked is what is really needed and iterative cycles will help to identify this. It also helps to be output-driven when there are limitations in terms of what can be produced and trade-offs have to be made.

Summary

- The real-time approach is very ambitious. Where timeframes for making decisions are short, the system will provide useful support but it should not be oversold, resulting in raised expectations.

  Function of the blackboard – a platform to bring people together and facilitate communication.

- Actual goals of ISIS? Main aim is to integrate all materials from site characterisation and constantly feed these into system. Not just geo-links – has to be a bigger picture.

- Stepwise approach – building in more modules as the programme advances.

- Toolkit/working environment aspects. The latter expedites communication/collaboration and is feasible now. Toolkits provide optimum support to users based on requirements and should be constantly evolving.

- Clearly define boundaries – user participation needs to be paramount from now on.
- Using system backwards, driven by required output. No stamp collecting!

KMS approaches within ISIS

Are the approaches adopted reasonable? Is the level of work representative of the state of the art? Do the chances of reaching a successful output seem sufficiently high?

In the bigger picture of the KMS/ISIS, the approaches are good, but there are still reservations with the real-time approach. What will be useful in the next 2 years, for example, will be groupware, chat functions, streaming, etc. which could help, for example, in drilling projects.

ISIS is not starting from scratch. It is based on the JAEA Geosynthesis Data Flow Diagram / RWMC SIFD (Site Information Flow Diagram) project linking raw measurements to end use. ISIS is a type of new generation tool for adding functionality to these geosynthesis methods, allowing the site investigation programme to be tailored to specific sites. Dynamics have to be incorporated into site investigations, bringing IT and knowledge engineering into the flow chart for geosynthesis.

Regarding the Eh example, will ISIS also have functionality as an interpretation tool? Interpretation will always involve expert teams. The software will help to link information for identification of trends and regional pictures, presenting all data together. The software could also test correlations between data and provide guidance to the expert teams who will make the interpretations externally using state of the art modelling tools.

The message is to manipulate the data when you can, distribute it with groupware and then use it as a basis for interpretation.

Summary

- Overall, the approaches are good. Reservations with real-time systems and what they can provide.

- Next 2 years – start with simpler options such as groupware, chat functions, streaming, etc., providing a gradual easing in to the concept.
- ISIS is not starting from scratch. Information flow is clear – what is being added is dynamics - functionality and the possibility for stepwise tailoring and optimising of site characterisation programmes for specific sites.
- Where is the interpretation function? Expert systems can present integrated data, test correlations and provide guidance for people who will (externally) make interpretations. But do not overestimate system capabilities.
- The approach should be to manipulate data when you can, distribute it with groupware and use it as a basis for interpretation.

Output

Have the results to date been clearly presented? Are interpretations and conclusions well supported? Do proposals for future work seem reasonable?

If this is a support system, does it log the results of decisions? NUMO will make decisions within the framework of its NSA (NUMO Structured Approach) and this will define the record-keeping structure. The functionality of record-keeping – logging decisions to build up a case base – has high priority. This leads into change management and the knock-on effect (i.e. how the downstream is affected).

Improvements

Dictionaries are critical (ontology), as is consistency. Caution should be exercised with links to external websites – the web is volatile and sites regularly disappear. It will be necessary to download critical information from the web and capture it in your own system.

The issue of digital data preservation is very important. This needs a background programme to preserve data on the long term. The issue of database security also has to be addressed.

The automated data search/synthesis function could be dangerous. If using this for the safety case it is essential to ensure quality. The intention is not to put computer-generated data directly into the safety case, but work effort can be minimised (e.g. using smart search engines – again a survey of available techniques still needs to be addressed). This can reduce the amount of information an expert has to consider by using appropriate criteria. Decision logging is very important.

The appropriate balance of automated systems and the human component always has to be borne in mind.

Final KMS/ISIS discussion

It was noted that the workshop has been an example of expert elicitation – information and experience have been obtained from experts and has been brought back to them at the end. Added value has been gained from the second iteration in the closing discussion.

Final comments

The long-term momentum of the system is a concern. It is not just JAEA that will have to maintain it. Financing over the long term is also an issue. This all relates to system sustainability. A stepwise approach is essential.

Creating knowledge is human and requires information. Human interfaces are very important (students, staff, contractors, etc.). There should be more emphasis on the human aspect. This leads on to a new issue – making people aware and changing the way they think, e.g. teaching the professors before you teach the students. KM is not taught as part of scientific training/education but perhaps it should be.

Getting people to buy into the system is difficult. They have to see the benefits for themselves. The cultural change will be hard to overcome. People will have to keep using the system and the system will have to evolve and grow with time.

The big question is "So what?" What happens if we do it and what happens if we don't? This helps to focus where priorities and benefits might lie. We may see the benefits but other potential users also have to.

Simply presenting people with an end-product is not transparent. Their requirements and needs have to be built into the system. From this perspective, the ISIS ES system shown is not quite convincing, but it is still a prototype.

It would be possible to set up a test community of users to try out the system. The issue is to try to keep attracting the rest of the scientific community.

It is important not to oversell the system or make expectations of what it can do too high. There is a thin line between motivating people to use the system and overselling it.

QA is built into the system to some extent. The link between KMS and QA is a selling point. As you do your business within the KMS, you are already doing QA. If QA is integrated, then people have to deal with just one system. The QA workshop planned for the beginning of next year will be very important.

Knowledge management should not be isolated as a separate activity. It is a human activity that we have all been doing since we were born. What the systems here are doing is formalising it, creating knowledge at the appropriate time and making it accessible.

Workshop to review the progress of development of a Knowledge Management System (KMS) and application towards advanced performance assessment (PA)

13th to 14th November 2008

This record documents discussions during the review workshop. The information follows the sequence of presentations during the workshop and reflects the questions and comments generated by each presentation. Comments are not assigned to individual reviewers. The first two presentations had the same title as those for the KMS ISIS workshop, but the content differed somewhat, producing some new audience feedback.

Day 1

First presentation: The JAEA KMS – concept and approach (H. Umeki)

Questions and discussion

The components of the KMS

The slide (20) showing the structure and components of the KMS is somewhat abstract. Is such a system sustainable? One practical aspect will be establishing the right teams at the right time. A small active team exists at present but this will be more problematic on the long term.

In an informal sense, the Knowledge Office will include the implementer, regulator, etc. Users will provide feedback, creating an autonomous system. However, self-organising systems are difficult to maintain and there is the question of how people can be made to use the system. The advantages of the system have to be made clear. People need to see the benefits.

A team with experts and knowledge engineers will be needed from early stages. At the present stage, the system shown sufficient – the next move will be towards further optimisation.

The argumentation network represents needs and requirements of users. Need to combine the KMS with NUMO's RMS.

Coolrep

The Coolrep concept – a new approach to reporting – was demonstrated using a preliminary draft(NB this draft is intended only to demonstrate the functions and structure of Coolrep concept and the content is still very much provisional.). The capabilities of the system were demonstrated. The fundamental idea is to address as wide a range of users/stakeholders as possible by structuring information, allowing people to take what they want from the "report". The approach makes extensive use of interactive features, animations, tutorials, etc.

Second presentation: Design and development of the KMS with the emphasis on advanced PA methods (K. Hioki)

Argumentation networks

How will an argumentation network function in practice? Is it effectively a roundtable of experts who all log in their arguments and counter-arguments?

The network will be linked with groupware so that people can make claims and launch attacks (like a roundtable). The users will include R&D staff to provide knowledge, generalists and decision makers.

Filling in the argumentation scheme leads to structured claims/arguments. This helps in being prepared for critical questions and thinking in a dialectic manner.

There is some similarity between making the safety case and arguing a legal case; both employ multiple lines of evidence. The safety case is classified as "non-monotonic" – as arguments and claims are not black and white and hence can be refuted.

It was unclear whether the argumentation scheme is really open. In any case it is intended to encourage dialogue, unlike e.g. FAQs on a website, which are often not generated by users but are prefabricated by the website producers.

Quality assurance

The knowledge note that records knowledge used in argumentation is hard evidence. How do you control the quality of the note?

The overall QA issue needs to be addressed, particularly when using external sources. Quantifying the level of confidence in the whole picture – how can you measure this? An option is evidential support logic – people assign quality/confidence and this is calculated. The argumentation network itself provides some indication of confidence – and indications of threats.

Argumentation schemes can become messy and software is needed to manage them. The more you use them the more useful they become. The system using argumentation networks forces you to think of counter-arguments, which is useful for QA. The example of Japan and Switzerland alternately reviewing one another's performance assessments shows that there can be drawbacks in this approach as reviewers become too close to the QA process. Argumentation networks make reviewing easier and they are an easier way to make a safety case.

Third presentation: Application of KMS technology towards advanced PA: concept and approach (K. Miyahara)

In the presentation, low alkali cement was selected as a high profile issue.

Scope of the system

Can the system consider the possibility of e.g. a spent fuel repository? The answer is yes – the system is forward-looking and considers the advanced nuclear fuel cycle. It is possible to scope direct disposal of SF using this system. If there is 14% fusion power by 2100, as mentioned in a recent JAEA study, the rationale for reprocessing might change. Direct disposal is not considered in Japan at present but the system needs to be future-oriented and the framework prepared for considering such issues.

Clearly, issues such as direct disposal of spent fuel will not be taboo questions for the implementer or regulator.

Software issues

Software interoperability is an important issue. When you move models between packages you can lose some of the richness of the model. Compatibility is better now but it is not 100%. If you add the time dimension to this, you have to consider old and new software packages.

Fourth presentation: Application of KMS technology towards advanced PA: design and development (H. Makino)

Tools

The calculations here (e.g. QPAC) are platform-dependent. It is important to use platform-free technology. Cloud computing is a possibility. The data and knowledge bases also have to be platform-free.

So far, the choice of tools has been very individual. A unified approach is now needed.

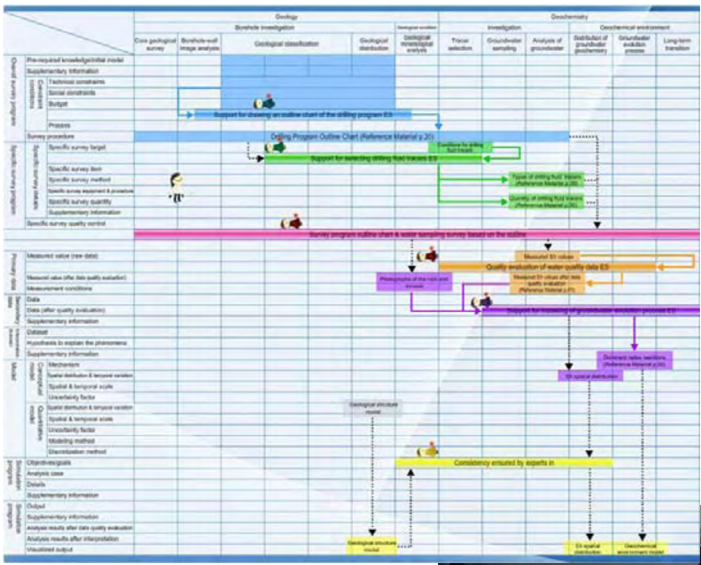
All-in-one report

Regarding the all-in-one report, what is the value of the report and who writes the conclusions? The real thinking still has to be done by people; the advantage lies in assisting with cumbersome, repetitive tasks that can be automated. Inventive problem-solving and standard work tasks lie at the extremes of the PA spectrum and the all-in-one report addresses only the latter.

When reviewing PA, there are often inconsistencies due to people using different versions of datasets. The all-in-one report solves this and ensures that everyone is using the same version. You cannot take the human element out – the system is still hybrid in this sense – but it ensures that different groups are using the same data.

Wiring in the report and using the all-in-one approach is acceptable for the base case as it ensures consistency of numbers. However, for scenarios the all-in-one approach is not appropriate. It cannot be used to change the conceptual model – this is something completely different. Again, the point is not to oversell the system and raise false expectations. The report will not write conclusions. The system has clear limitations and has to be used with care. It is aimed primarily at reducing the workload in certain areas.

Some issues were raised with respect to appropriateness of terminology, e.g. deep and shallow knowledge, blackboards, etc.



Day 2

Structured discussion session

Initial presentations were made by the implementer, regulator and academia in response to the material presented on the previous day.

Implementer

- The KB as a fundamental information source for the Requirements Management System (RMS) of NUMO will ensure more efficiency. The RMS is still in the test stage focusing on repository concepts development and will be extended to siting, etc.
- The communication interface is important for users who want an easy, simple and flexible system.
- Quality and credibility are still open issues.
- More exchange and discussion with users is needed.
- JAEA’s current developments are in line with NUMO’s needs.

Regulator

- Particularly for licensing, the all-in-one report and Coolrep approach linked with the knowledge base will be useful for the regulator for review purposes. They provide better traceability, transparency, access to information and communication with the applicant.
- It is important to create a link with knowledge relevant to safety regulations – international guidelines and past licensing processes represent key resources. Consistency with past licensing decisions is important.
- The database needs to be objective and neutral.
- Argumentation diagrams could be used in developing specifications for regulations and demonstrating compliance. They make it easier for the implementer to see what he has to do. This would result in clearer regulations and identification of what has to be in the safety case.

Academia

- A perspective is still needed on the overall KM system. So far the presentations have focused on the details of knowledge management.

- The academic system in Japan produces specialists. Some of the generalists in the field have been around for almost 30 years and will soon be lost. It is important to produce generalists as quickly as possible, but the challenge is how to do this. The ability to think outside the "box" (a specific area) is being lost. Generalists can think outside the "box" and see the problem in context.
- It may first be necessary to educate in philosophy – it is difficult to teach the bigger picture. An approach such as Coolrep could help here. Learning by working with experienced people is important; this would need the support of the professors in finding the right people and the right projects.

General points

The system still needs something added to give perspective. Generalists can only go so far and reach their limits at some point. Then you have to rely on the specialists.

Fundamental questions such as why do we need this type of disposal system may arise. Such a discussion should be included in the KMS.

The safety case has to include the balancing of the whole programme (costs, environment, socio-political aspects, etc.). A proper definition of the safety case is necessary and this has to be developed and communicated. The database has to be neutral and bringing in e.g. political and financial considerations is difficult, but these can affect the safety case. This is the responsibility of NUMO.

A system is needed for users such as the host community, Greenpeace, etc. Everyone should have access to the same information and it needs to be consistent, particularly with the volunteering approach adopted in Japan.

KM is used in other industries. Comparison of experience may be beneficial – key lessons learnt, failure stories, etc. There are other areas with huge information fluxes, for example the Large Hadron Collider in CERN. The software manages huge volumes of data which is processed numerous times to produce metadata that people actually look at.

The information explosion relates to information, which is something different from knowledge. There is a gap between knowledge and information – much of the latter is irrelevant. The information explosion is almost a side issue. KM systems should help us to see changes in data and to identify the effect on the system.

It is not the intention that the KMS will totally replace peer review and expert advice.

Structured discussion summary

Only points not covered elsewhere are presented here.

KMS goals

The goals are clear. Different tools are shown for different steps and this is clear, but what is missing is the overall structure. How, as a user, do you move through the whole process from raw data to the final decision? What is the backbone of the system? It is clear what is possible but not always where to apply it.

The next step will be to integrate the KMS/RMS, etc. Input is needed from the users to define the steps in the process. Diverse tools have been presented but a structure and concept are needed. This is a priority for the coming year.

The KMS is not a safety case. Is the KMS itself a paradigm shift or should it reflect paradigm shifts that are occurring in the real world? Changing the culture of radwaste management organisations will be a major challenge. The KMS is ultimately a tool.

It is necessary to return to considerations of strategic planning and to decide how to assist users. Developments in the last 2 years have moved away from the strategic level. The tools are good and helpful and in line with trends but they need to be user-oriented and not just developments for the sake of developments.

The emphasis in the last 2 years has been on seeing what works. Now is the time to talk to the users. The development team may have become too close to the tools. These need to be better defined and described and the terminology used needs to be reconsidered.

The project aspirations are clear, but the goals are less clear. This may change if the strategic aspects are revisited and the goals will crystallise out. It has to be clear what is being delivered in 2 years. Goals have to be reasonable and prioritised.

Who structures the blackboard and what is its real function? How sustainable is it? It is not always clear who is doing what. Ultimately the field researchers will change the blackboard as site investigations progress. The blackboard represents shared working memory. The idea is to leave information for people which they can then come and pick up and note that they did so/what they have done with it. It is not really a roundtable. The control shell (mother) works on meta-knowledge (generalist).

NUMO holds roundtable discussions to design tasks for site investigation. JAEA has tools and expert systems. NUMO decides its goals and aims and takes what it wants from the system. The blackboard will be actions and tasks decided by NUMO, who can make their own modules.

In terms of system sustainability, before delivering the system to e.g. NUMO, there have to be interviews to determine how they want it to be tailored. The system has to be so user-friendly that people will buy in and continue to use it. What will be delivered is a mixture of concepts, tools and databases.

Nomenclature should be used that allows people to actually understand the fundamental issues, e.g. the blackboard concept. Knowledge engineering jargon is not always appropriate.

How confident can you be in the output? How reliable are the choices made? When there is uncertainty (which there effectively always will be), it is wrong to force one answer. Lateral thinking and capturing uncertainty are important.

More of the communication should be done with demonstrations.

There is a need to clarify what KMS comprises and the difference between KM and KMS – it is time to revisit fundamental ideas.

KMS approaches - general

The whole aspect of definitions/terminology needs to be clearer.

Need for integrated teams of knowledge engineers and experts to ensure system sustainability – long-term perspective. Not a one-time buy in. Having the right team and the right perspective at the right time is important.

Tools should act as aids and it should be clear where the human element comes in. Overselling may create problems and raise false expectations.

The Coolrep approach received a positive response. It was identified as a useful tool for all users. Important aspects are communication and hierarchical structuring of knowledge, making it possible for people to take what they want from the system. There will be no taboo questions – such a platform allows stakeholders to ask any questions they wish.

KMS approaches within PA

Questions were raised regarding value of approaches – e.g. the all-in-one report. The role of this needs to be made clear. The aim is to take away routine work tasks and insert quality control. The human element cannot be removed. The system has clear limitations and should be used with care.

Summary of key points

- Importance of terminology – use terms that people understand. KE terminology not always appropriate. Deep/shallow knowledge, etc.
- Use more demonstrations to communicate.
- Make systems platform-free – now at a stage to do this.
- Revisit fundamental KM concepts to provide perspective.
- Software interoperability needs to be addressed.
- Consider a careful balance of automated systems/human component.

Final discussion

Digital data preservation and system sustainability are key issues.

The system is very important for task communication – we have to show what we know and what we do not know.

Collaboration: Users will now be approached, including younger academics.

A lot can be taken away by the experts attending the workshop. There is a wide recognition of the need for KM and discussions about the theory and need for KM are effectively exhausted. JAEA have taken the lead in applied system development. However the process should be two-way – taking away the experience of JAEA but also giving something back.

Possibilities for collaboration may exist in the area of carbon capture and storage (CCS), which is also looking at PA. Many issues will be similar.

Afterword

Following the workshops, JAEA has been receiving positive feedback from participants, particularly the foreign experts. Two examples are given here.

"May I thank you (H. Umeki), the JAEA staff and other Japanese colleagues for hosting this workshop. From my point of view, it was very interesting, informative and open, allowing participants to feel able to make positive and helpful contributions. I look forward to seeing how your systems progress over the next 12 – 24 months.

I believe everyone agreed that the programme you have embarked upon will be challenging but, with the continued cooperation of stakeholders and the international community, you will remain 'on course'. I support your thoughts regarding future collaboration on this topic." (Ian Upshall, NDA, UK)

"Thank you very much for the opportunity for the NEA to participate in the workshop. I fully agree with the sentiments that Ian Upshall (UK NDA) expressed already in his reply to your note and found the workshop to be extremely interesting. Despite having heard you speak quite a lot on the concept of the JAEA KMS, I did not fully appreciate the scope or ambitiousness of the project. I am also impressed by the practical progress and tools that were demonstrated. I think JAEA is, for the moment, leading the international community on this topic but – as was agreed at the workshop – the need for such approaches is 'no-brainer', so you will not be alone for too long, I hope. I will give more though to the role of the NEA in fostering more dialogue and encouraging cooperation." (Betsy Forinash, OECD/NEA, Paris)

This record has been compiled by Linda McKinley and reviewed and confirmed by the participants in November 2008.

APPENDICES

- List of Participants

- Program for Workshop to Review the Progress of Development of a Knowledge Management System (KMS) and an Integrated Information Synthesis and Interpretation System (ISIS) - JAEA KMS/ISIS Workshop
- Overview of JAEA KMS/ISIS Workshop
- The JAEA KMS: Concept, Approach And Application To Geosynthesis
- The JAEA KMS: Design and Development, With Emphasis on Geosynthesis
- ISIS: Concept and Approach
- ISIS: Design and Development
- The JAEA KMS & ISIS: Structured Discussion Session
- Comments on Workshop of KMS and ISIS

- Program for Workshop to Review the Progress of Development of a Knowledge Management System (KMS) and Its Application toward Advanced Performance Assessment (PA) - JAEA KMS/PA Workshop
- Overview of JAEA KMS/PA Workshop
- The JAEA KMS: Concept, Approach and Application to Developing Advanced PA Technology
- The JAEA KMS: Design and Development, With Emphasis on Advanced PA Methods
- Application of KMS Technology toward Advanced PA: Concept and Approach
- Application of KMS Technology toward Advanced PA: Design and Development
- Presentation Context for Discussion Session of KMS and PA
- Comments on the Development of KMS and Advanced Performance Assessment
- What Can The Regulators Expect The JAEA KMS In Terms Of PA?

JAEA KMS Workshops, Tokyo, 11-12 and 13-14 November, 2008
List of Participants

	Name	Organisation	Country	ISIS(11-12 Nov.)	PA(13-14 Nov.)
Invited Experts					
1	Elizabeth Forinash	OECD Nuclear Energy Agency	France	○	○
2	Richard Shaw	British Geological Survey	UK	○	○
3	Ian Upshall	Nuclear Decommissioning Authority	UK	○	○
4	Kenzi Karasaki	Lawrence Berkeley National Laboratory	USA	○	○
5	I. Blechschmidt	Nagra	Switzerland	○	
6	J. Rueedi	Nagra	Switzerland	○	○
7	Yasuaki Ichikawa	Nagoya University	Japan	○	○
8	Sumio Masuda	Secretariat, Nuclear Safety Commission	Japan	○	○
9	Tadashi Miwa	Nuclear Waste Management Organization of Japan	Japan	○	
10	Tai Sasaki	Japan Nuclear Fuel Limited	Japan	○	
11	Haruo Yamazaki	Tokyo Metropolitan University	Japan	○	
12	Katsuhiko Ishiguro	Nuclear Waste Management Organization of Japan	Japan		○
13	Hiroto Kawakami	Japan Nuclear Energy Safety Organization	Japan		○
14	Kazuaki Matsui	The Institute of Applied Energy	Japan		○
15	Osamu Tochiyama	Nuclear Safety Research Association	Japan		○
JAEA&Contractors					
16	Masahide Osawa	Japan Atomic Energy Agency, Tokai	Japan	○	○
17	Hirohisa Ishikawa	Japan Atomic Energy Agency, Tokai	Japan		○
18	Hiroyuki Umeki	Japan Atomic Energy Agency, Tokyo	Japan	○	○
19	Kazumasa Hioki	Japan Atomic Energy Agency, Tokyo	Japan	○	○
20	Hideaki Osawa	Japan Atomic Energy Agency, Tokyo	Japan	○	○
21	Takeshi Semba	Japan Atomic Energy Agency, Tokyo	Japan	○	○
22	Hitoshi Makino	Japan Atomic Energy Agency, Tokyo	Japan	○	○
23	Yasuhiro Ochi	Japan Atomic Energy Agency, Tokyo	Japan		○
24	Naoki Sugiyama	Japan Atomic Energy Agency, Tokyo	Japan		○
25	Katsuhiro Hama	Japan Atomic Energy Agency, Tono	Japan	○	
26	Shinji Takeuchi	Japan Atomic Energy Agency, Tono	Japan	○	
27	Kenji Amano	Japan Atomic Energy Agency, Tono	Japan	○	
28	Hiromitsu Saegusa	Japan Atomic Energy Agency, Tono	Japan	○	
29	Teruki Iwatsuki	Japan Atomic Energy Agency, Horonobe	Japan	○	
30	Kunio Ota	Japan Atomic Energy Agency, Horonobe	Japan	○	○
31	Takanori Kunimaru	Japan Atomic Energy Agency, Horonobe	Japan	○	
32	Michiko Shigehiro	Japan Atomic Energy Agency, Horonobe	Japan	○	
33	Akio Nakayasu	Japan Atomic Energy Agency, Horonobe	Japan	○	
34	Takeshi Ebashi	Japan Atomic Energy Agency, Tokai	Japan		○
35	Akira Honda	Japan Atomic Energy Agency, Tokai	Japan		○
36	Kaname Miyahara	Japan Atomic Energy Agency, Tokai	Japan		○
37	Atsushi Sawada	Japan Atomic Energy Agency, Tokai	Japan	○	
38	Toshihiro Seo	Japan Atomic Energy Agency, Tokai	Japan	○	
39	Kazuhiko Shimizu	Japan Atomic Energy Agency, Tokai	Japan	○	
40	Ian McKinley	McKinley Consulting	Switzerland	○	○
41	Linda McKinley	McKinley Consulting	Switzerland	○	○
42	Hiroo Okubo	Mitsubishi Research Institute, Inc.	Japan	○	○
43	Shiro Udoguchi	Mitsubishi Research Institute, Inc.	Japan		○
44	Miyoshi Yoshimura	Dia consultant	Japan	○	
45	Young Ah Yoon	Dia consultant	Japan	○	
46	Hiroyasu Takase	Quintessa Japan	Japan	○	○
47	Shoko Tachibana	Quintessa Japan	Japan	○	○
48	Yu Sato	Geoscience Reseach laboratory	Japan	○	

2008-10-30

Workshop to review the Progress of Development of
a Knowledge Management System (KMS) and
an integrated Information Synthesis and Interpretation System (ISIS)

11 to 12 November 2008

Organizer:
Japan Atomic Energy Agency (JAEA)

Venue:
Tokyo Marunouchi – Pacific Century Place 8th Floor
1-11-1 Marunouchi, Chiyoda-ku, Tokyo, 100-6208, Japan

Program

10 am to 5 pm, Tuesday, 11 November 2008

1. Opening Remarks by Mr. Masahide Osawa, Director General, Geological Isolation Research and Development Directorate, JAEA

2. Presentations on the JAEA Knowledge Management System (KMS)
   - Concept and Approach — Hiroyuki Umeki
   - Design and Development — Kazumasa Hioki
   - Discussion

3. Presentations on ISIS
   - Concept and Approach — Hideaki Osawa
   - Design and Development — Takeshi Semba
   - Discussion

10 am to 4 pm, Wednesday, 12 November 2008

4. Discussion of the projects
5. Summary of comments made based on the questionnaire

JAEA KMS/ISIS Workshop

- Objectives
  - Present the current progress of JAEA activities on KMS and ISIS
  - Solicit review comments from the participants
  - Discuss how such comments could be reflected in future work, possibly including collaboration in areas of common interest
- Participants
  - All invited (international and Japanese experts)
- Information to be presented
  - Status of ongoing projects
  - Most of the detailed project output is being presented for the first time in English
- Outcome
  - A meeting record will be openly available (JAEA website?), which will include a compilation of the material presented

Questionnaire

- Are the project goals clear and adequately justified and the effort invested appropriate to requirements?
- Are the approaches adopted reasonable, the level of work representative of the state of the art and the chances of reaching a successful output sufficiently high?
- Have the results to date been clearly presented and are interpretations, conclusions and proposals for future work reasonable?
- Are there ways in which the project could be improved?
- Are there any areas where collaboration with other organizations would be beneficial?
- Any other comments?

JAEA KMS/ISIS Workshop

Programme

Day #1 (Moderators: H. Umeki / I. McKinley; Rapporteur: L. McKinley)

10:00 - 10:05	Welcome (M. Osawa)
10:05 - 10:20	Introduction to workshop and participants
10:20 - 11:20	JAEA KMS: Concept and Approach (incl. questions) (H. Umeki)
11:20 - 11:50	Break
11:50 - 12:50	JAEA KMS: Design and Development (incl. questions) (K. Hioki)
12:50 - 14:00	Lunch
14:00 - 15:00	ISIS: Concept and Approach (incl. questions) (H. Osawa)
15:00 - 15:30	Break
15:30 - 17:00	ISIS: Design and Development with Demonstration of the system elements (incl. questions) (T. Semba)
17:00	End

JAEA KMS/ISIS Workshop

Programme

Day #2 (Moderators: H. Umeki / I. McKinley; Rapporteur: L. McKinley)

10:00 - 10:05	Introduction to Discussion Session
10:05 - 11:05	Block 1 - the JAEA KMS
11:05 - 11:20	Break
11:20 - 12:20	Block 2 - ISIS and the application of KM to geosynthesis
12:20 - 14:00	Lunch
14:00 - 16:00	Block 3 - Review of comments & suggestions (incl. Break)
16:00	End

The JAEA KMS:
Concept, Approach and Application to Geosynthesis

Workshop to Review the Progress of the Development of
a Knowledge Management System (KMS) and
an integrated Information Synthesis and
Interpretation System (ISIS)

11-12 November, 2008
Tokyo

Hiroyuki Umeki

Presentation context

The JAEA KMS

- **Why and what?** **Umeki**
- How and when? Hioki

} ISIS as an example of a key application

Presentation outline

- Generic overview and need for KM in geological disposal projects
- Specific background in Japan
- Initial concepts and constraints
- Application of advanced concepts from Information Technology and Knowledge Engineering
- Critical applications - geosynthesis
- Special near-term goals – the “Coolrep” concept
- Summary of big messages

Why worry about knowledge management?

- Until the time of the Renaissance, it was possible for a genius to master all major areas of the arts and sciences (e.g. da Vinci)
- With the exponential explosion of knowledge in the 19th & 20th centuries, it became impossible for an individual to master all aspects of even a single scientific discipline
- By the end of the 20th century, mastering even a sub-discipline became extremely difficult and the integration of multi-disciplinary projects was acknowledged to be a major problem
- As exponential knowledge growth continues during the 21st century, the ability to manage information may be the most critical aspect of many projects

The information explosion

Conventional KM includes:

- Compilation & recording - documents & databases
- Structuring & preservation - libraries & archives
- Quality assurance - compatibility checks & peer-review
- Synthesis, integration & planning – expert groups; summarised in annual reports, topical reviews & R&D plans

⇒ basic procedures established in early civilisations and have changed little: key role of experts (gurus) to provide guidance

2007 digital universe

- Data inventory- **280 EB**
- **Exponential growth** in production, transfer and storage with doubling time ca. 1.5 years (i.e **order of magnitude every 5 years**)

(http://www.emc.com/collateral/analyst-reports/diverse-exploding-digital-universe.pdf)

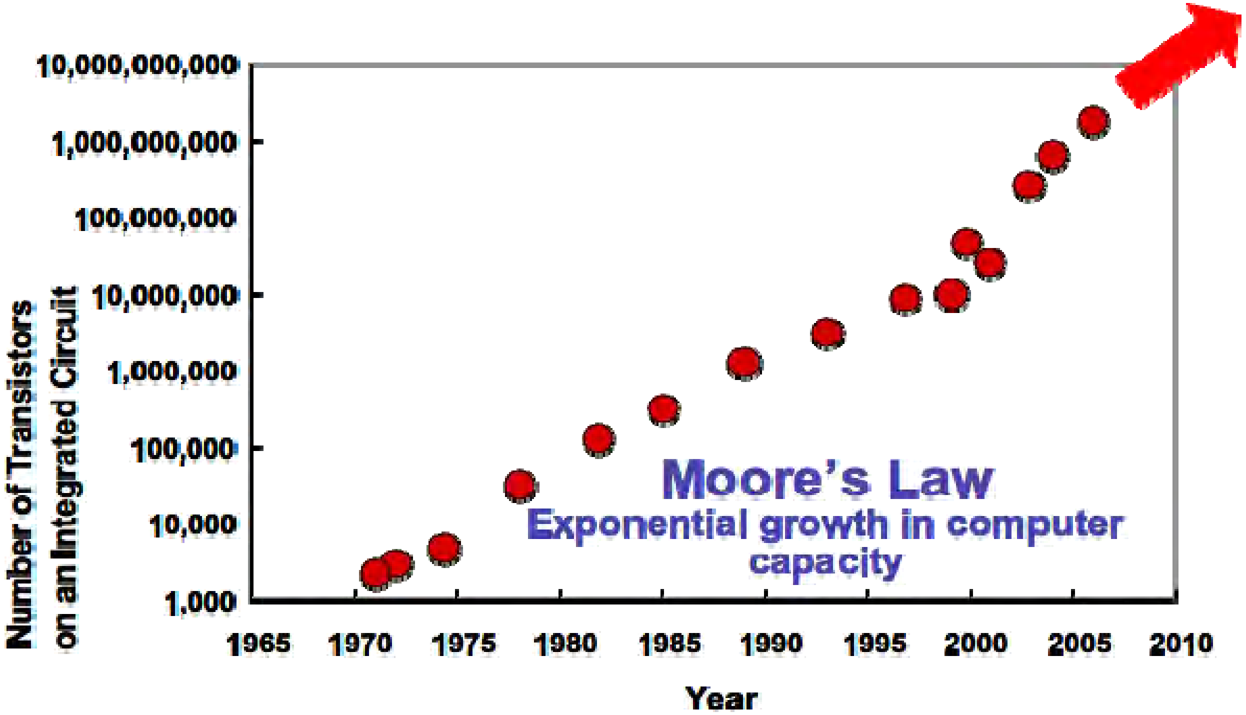
Kilobyte (kB) 10^3bytes
2 kB: A Typewritten page
Megabyte (MB) 10^6bytes
5 MB: The complete works of Shakespeare
Gigabyte (GB) 10^9bytes
100 GB: A library floor of academic journals
Terabyte (TB) 10^{12}bytes
10 TB: The print collections of the U.S. Library of Congress
Petabyte (PB) 10^{15}bytes
200 PB: All printed material
Exabyte (EB) 10^{18}bytes
5 EB: All words ever spoken by human beings
(http://www2.sims.berkeley.edu/research/projects/how-much-info-2003/execsum.htm)

Specific issues for geological disposal

• Information explosion parallels - and is driven by - exponential growth in computing power (continually exceeding expectations – **rate of growth** of information has climbed from 2002 to 2007; doubling time dropped from 3 to 1.5 years!)

• Clearly especially problematic for areas like radwaste disposal; multidisciplinary with very long implementation timescales

⇒ Breakdown of conventional approaches is evident here



Repository:

Operation ~ 2035?
10^6 x present capacity / speed

Closure ~ 2095?
10^{14} x present capacity / speed!!!

Evolution of disposal Knowledge Base

Inventory (“pages”) of key

Year	key documents	Literature	Databases	key databases
1940				
1950				
1960		10^4	10^4	
1970	*All on paper*			*Text / magnetic*
1980	*Most on paper*	10^6	10^7	*Magnetic*
1990	*Most electronic*			*Magnetic/optical*
2000	*All electronic*	10^8	10^{10}	*Optical/magnetic*
2010				

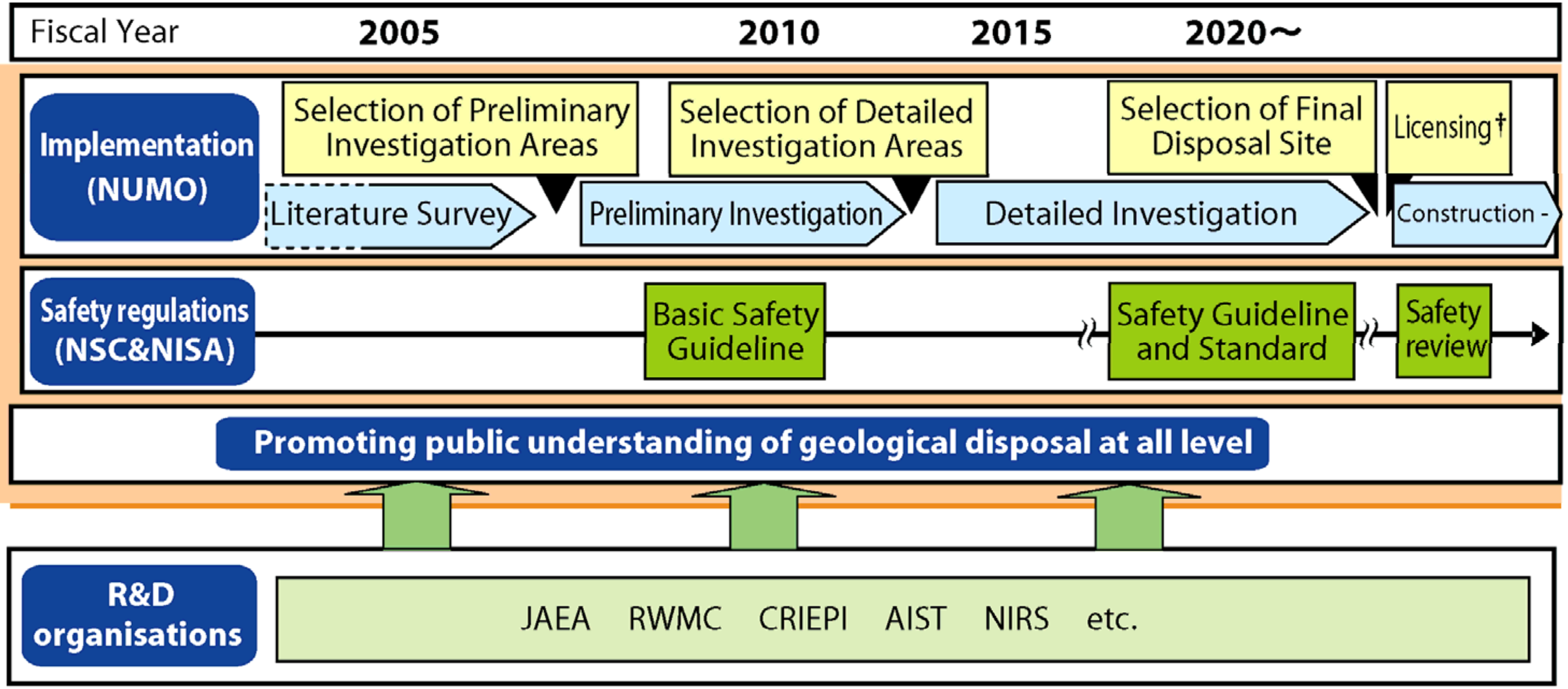
NB 1 “page” ca. 2 kB

Big Message (1)

Based on the volume of information to be handled, it is no longer a question of whether advanced KMS will be introduced into radwaste management programmes or not – only whether such systems can be developed and implemented before total collapse of conventional approaches!

The Japanese geological disposal programme

Stepwise implementation, with deadlines slipping…

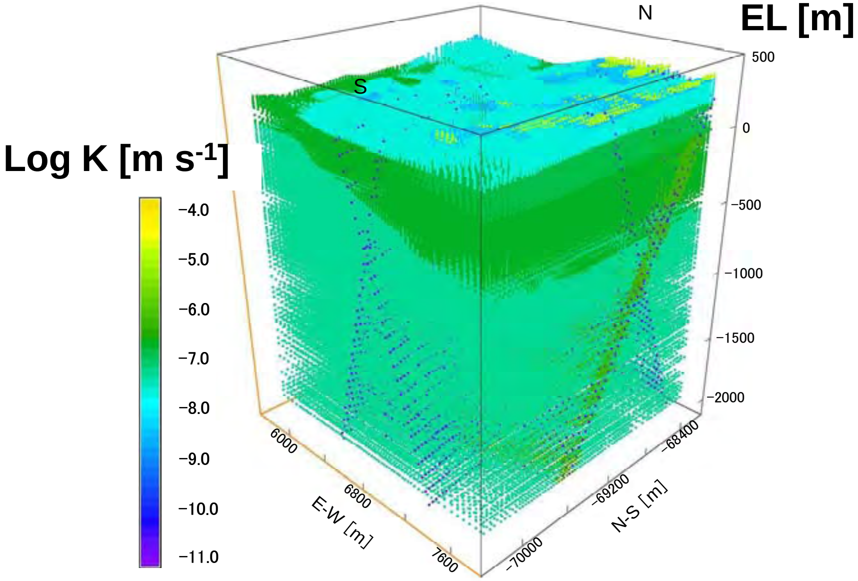


† Repository construction, operation and closure

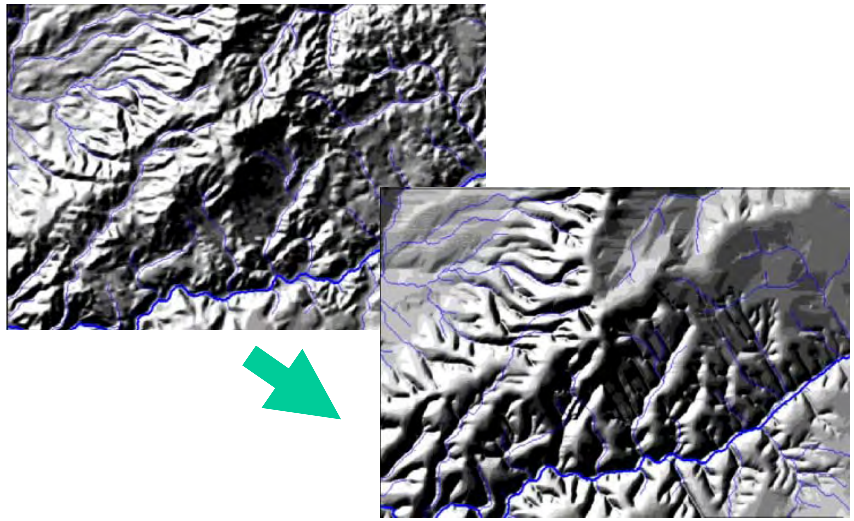
- ➢The Knowledge Management challenge clearly identified (JNC H17, 2005) and accepted as a key responsibility of JAEA (supporting both the implementer and regulatory groups)

Information explosion in R&D supporting geological disposal in Japan

- The size of the first integrated PA (H3) was ~ 400 pages, by the second PA (H12), 9 years later, this had expanded to ~ 2,000 pages.
- One of the greatest difficulties was integrating the huge amount of supporting information/data on geological environments, engineering and safety assessment.
- More recently, the volume of data has exploded as more synthetic modelling includes high resolution in 3D and explicit representation of evolution in time.



3D hydrogeological model showing distribution of hydraulic conductivity



An example of 3D topographical evolution predicted for Tono region

Special issues related to the Japanese programme

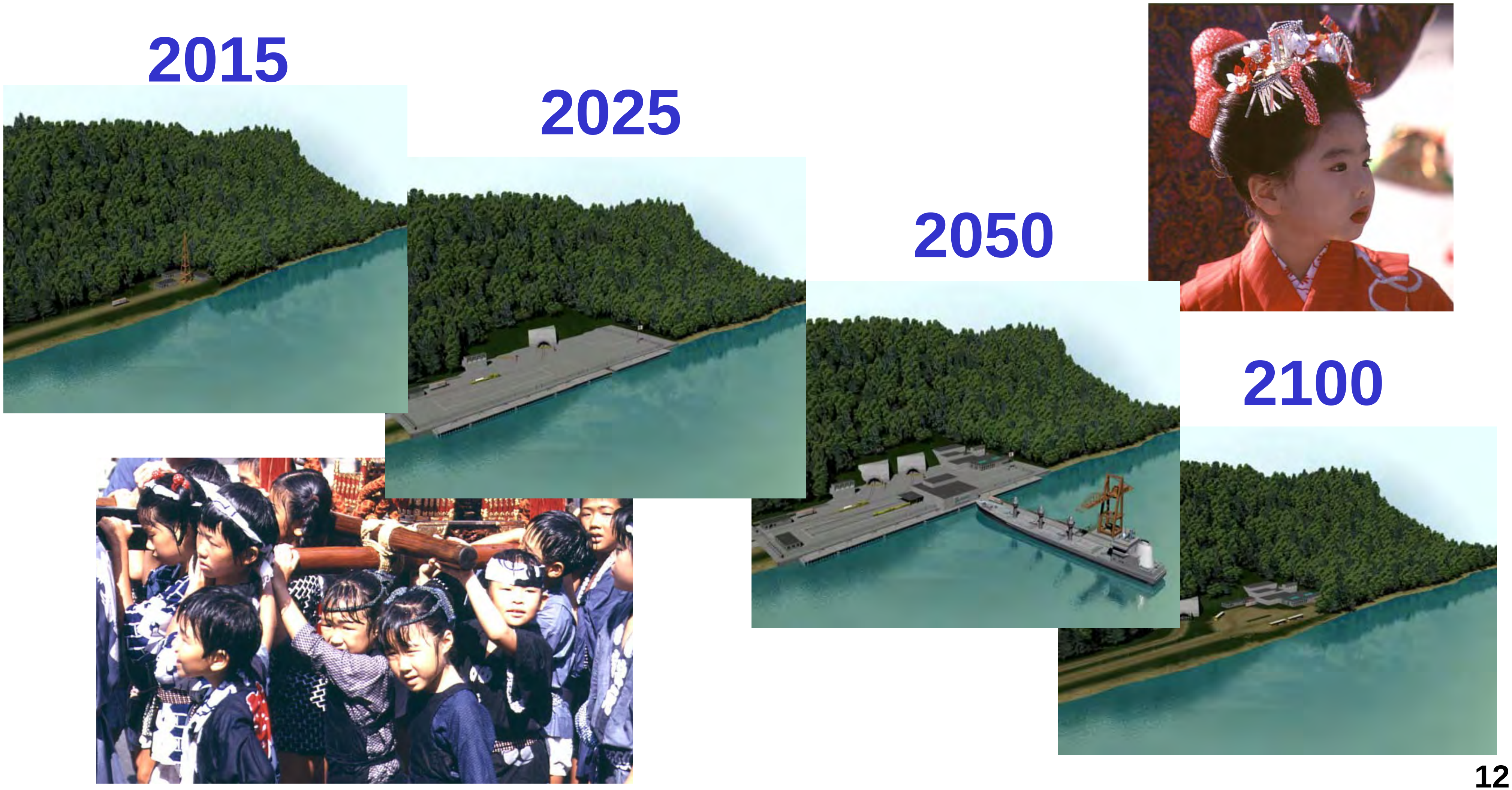
- Volunteering approach – uncertainties in timescales, site properties (potentially complex geology) and appropriate repository designs
- Tight schedule for early stages of site characterisation, which could run in parallel at several sites
- Considered for both HLW and “TRU” (separate facilities or co-disposal)
- Shortage of experienced staff and marked age bulge passing through all key organisations
- Commitment to openness and transparency

History of Radwaste / Human Resources

1940	No Concern	Small groups of physicists, chemists & engineers
1950		Growth of specialist nuclear-physics, -chemistry, -engineering
1960	Simple Solutions	
1970		Peaking numbers of specialists / increasing role of generalists
1980	"1st Gen" Concepts	
1990		Loss of experts / declining recruitment
2000		
2010	"2nd Gen" Concepts	Crisis? ...loss of experienced staff

Working life of staff

...we are struggling to plan the siting process now, so how can we ensure that teams have the knowledge to license and build future repositories?



Big Message (2)

The Japanese decision to rapidly move into advanced KM was driven by the boundary conditions of the national programme. In particular, imminent loss of many experienced staff as they retire leaves only a small window to capture tacit knowledge (common problem throughout the nuclear industry).

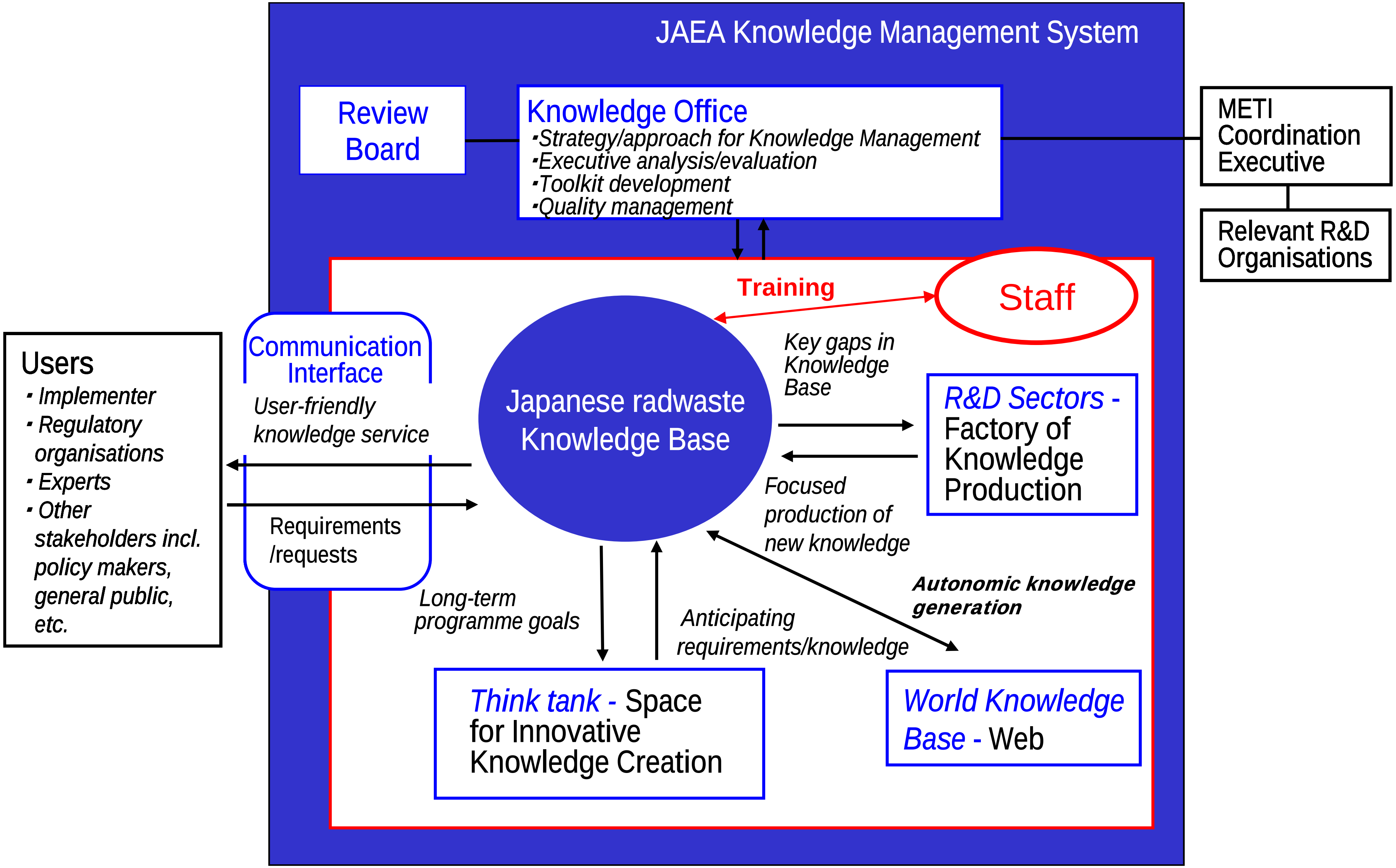
Fundamental concept of the JAEA KMS

- The fluxes of knowledge within a geological disposal programme are so huge that past informal approaches are clearly inadequate: formalisation of processes needs to be combined with adoption of **advanced KE technology**
- The KMS is not a passive tool to archive and disseminate information – it requires ability to autonomically synthesise and integrate material from diverse sources, identify trends and inconsistencies and give feedback to data producers.
- The KMS must allow for continuous exponential growth of the knowledge base
- Flexibility and user-friendliness is essential to encourage use by both knowledge-producers and -users.
- Emphasis is placed on advanced **electronic information management**; utilising experience in relevant areas such as **expert systems**, **artificial intelligence**, **neural networks**, **web-based agents** and **bots**, etc.

Big Message (3)

The problem identified is so fundamental that modification of conventional approaches offers no chance of solving it – a complete paradigm shift is required, which emphasises structured processes and use of advanced IT and KE methodology.

Structure and components of the KMS



Critical KMS components

- The Knowledge Base (KB) and associated archiving and maintenance tools
- Knowledge acquisition technology (for both explicit & tacit knowledge)
- Knowledge manipulation technology (for autonomic processing, quality checking, trend analysis, etc.)
- Flexible and user-friendly communication interface
- Training and transfer of tacit knowledge
- Executive coordination: including monitoring of progress and user feedback, quality management and strategy development (including initiatives to anticipate important future developments in technology or project boundary conditions)

Next presentation

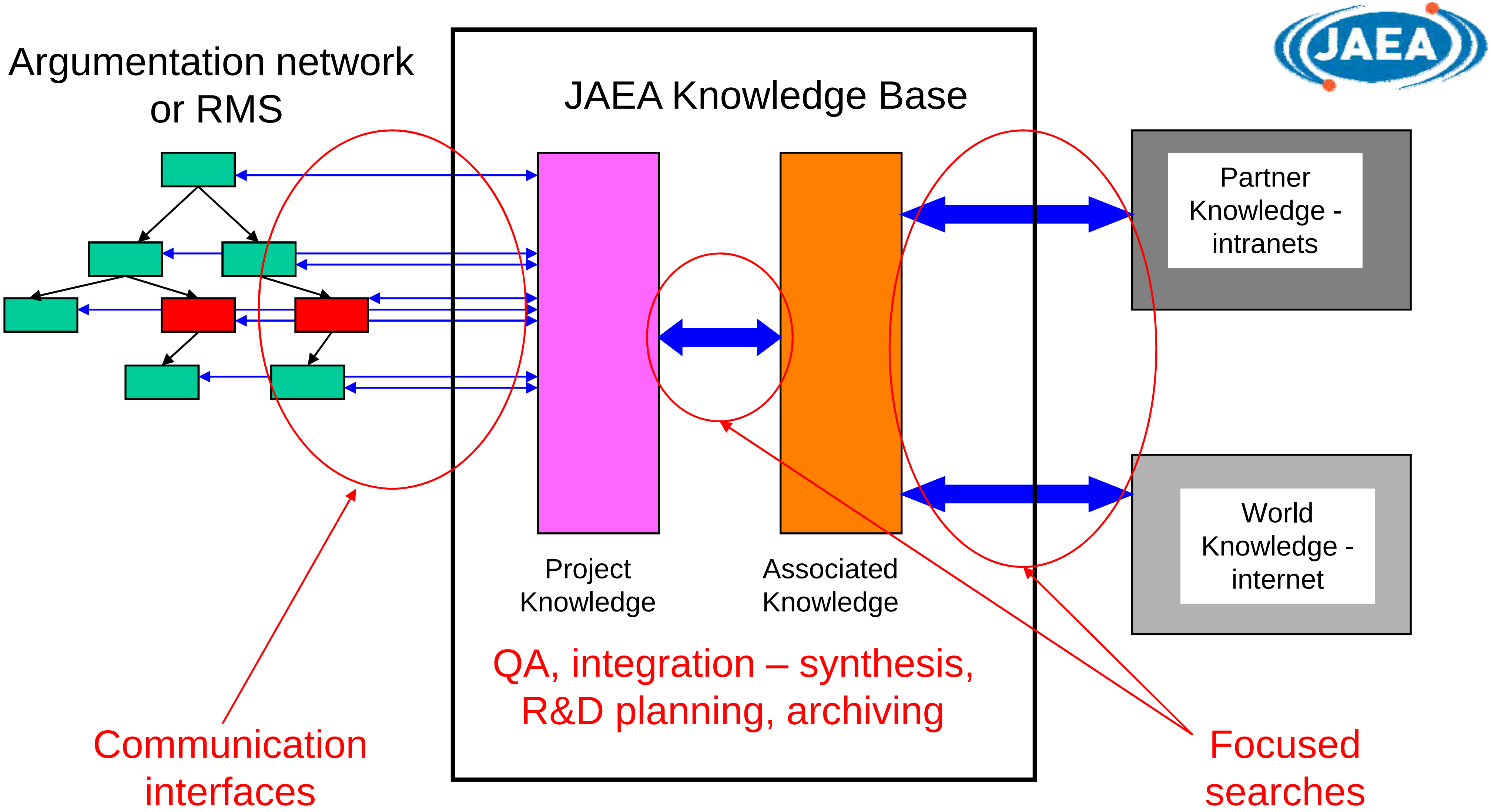
Components of JAEA knowledge base

Form of knowledge	Management functions	Content	Required developments	Comments
Data	Data management	- raw data (internal) - solicited data (external) - processed data	- autonomic QA - internal & external data mining - autonomic data processing	Potential area for international collaboration
Documents	Document management	- internal documents - key external documents	- robust archive - autonomic QA / cataloguing / cross-referencing	Electronic archiving critical problem area
Software	Software management	- archive of all relevant codes / databases - archive of manuals & handbooks - archive of relevant output	- robust archive - autonomic change management - formal approaches for QA	Electronic archiving critical problem area
Experience & methodology	Resource management	- procedure manuals & guidebooks - expert systems - training materials	- use of expert systems to preserve experience - training approach for the next generation	Much of requirements could be addressed by national (regional?) training centre
Synthesis	Knowledge integration	- experienced synthesis team - expert systems	- description of key integration processes - approach to QA	Needs considerable development to automate
Guidance	Knowledge coordination	- experienced coordination team	- prediction of requirements (Think tank) - process for filling key gaps in knowledge	Very difficult to automate
Presentation	User / producer dialogue	- user friendly interfaces (interactive – allowing dialogue)	- high-end graphical methods for presenting complex information	Should be tailored to needs of different stakeholders

Roles of the intelligent assistant

Concepts

- The **Knowledge Base (KB)** does not need to be rigorously structured;
  - Standardised vocabulary (ontology) allows application of smart search engines
  - Requires rigorous file management procedures and robust security
- The **Knowledge Management System (KMS)** serves to
  - Maintain, update and facilitate access to the KB (automated as far as possible)
  - Establish effective interfaces to Knowledge producers & users (utilising advanced communication tools)
  - Ensure development of the tacit knowledge required to perform tasks that cannot be automated (e.g. decision making)
- **KMS application** is driven by the needs of users (including knowledge producers), may be formally defined:
  - An interface to an established Requirements Management System (RMS)
  - An argumentation network flexible enough to fit the needs of all users



Roles of JAEA KB:

- **secure, traceable record of all knowledge applications (database freezing)**
- **specified reference data to compare against future developments, potential triggers for change assessment**
- **identification of gaps to allow focused searches / knowledge creation**

The “intelligent assistant”

- Integrates information technology support
- Helps establish ontology
- Incorporates a toolkit for
  - Compiling explicit knowledge - **knowledge mining tool**
  - Compiling tacit knowledge - **expert system tool**
  - Autonomic knowledge manipulation – **archiving, quality testing, synthesis, integration and documentation tools**
  - Knowledge presentation – **visualisation tool**

Toolkit development

- **Stepwise development of the intelligent assistant**
  - Establish nomenclature (ontology) for fundamental knowledge management
  - Establish nomenclature (ontology) for safety case development
  - Initiate development of essential components of the software in parallel (but with awareness of need to link)
  - Develop test cases to test applicability to real problems (NB output should be of immediate value to participants)
  - Analysis of test case applications – proposals for improvements

(iterates until applicable to entire safety case)

Feasibility of an "intelligent assistant"

In principle, feasible based on the observations that:

- Most of key information for repository projects
  - already available electronically and accessible via internet / intranet systems
  - reasonable to expect effectively 100% coverage in the near future
- Content-recognition & cross-referencing systems
  - increasingly sophisticated
  - allow relationships between documents and any form of datasets to be defined in much more detail than traditional approaches
- Autonomic data-mining techniques involving network agents
  - currently an area of very rapid progress
  - allows much of the information gathering, sorting and compilation processes to be automated
- Combination of expert systems with autonomic learning approaches (e.g. based on neural networks)
  - allows, at least in principle, many of the key processes involved in knowledge management – collation, synthesis, review, etc. – to be automated

Big Message (4)

The developments envisaged are ambitious but appear feasible based on current technology. The individual components needed all exist – they have just never been combined and implemented in the manner planned.

A special concern - tacit knowledge

- Most KM applications noted above focus on **explicit** knowledge - that which can be readily documented
- Just as important is **tacit** knowledge - information and experience which is contained in the heads of senior staff and plays a key role in planning and decision making - particularly in pragmatic areas of multidisciplinary projects
- Tacit knowledge has tended to be managed in the past via training / apprenticeships / on-the-job experience transfer, but this is now critical in many programmes due to retirement of staff who played unique development roles
- Special training and mentoring projects may be valuable, combined with more speculative, novel approaches (e.g. based on e-learning supported by expert systems)

Training and experience transfer

In the past rather ad-hoc, but needs careful planning in the future to maximise output from limited resources:

• special training based on international infrastructure (e.g. ITC), complemented by tailored courses on key topics of national relevance

• plan projects (especially interdisciplinary / international studies) to maximise experience transfer to young staff

• use of mentors to allow junior staff to gain experience in complex projects

http://www.itc-school.org/

Big Message (5)

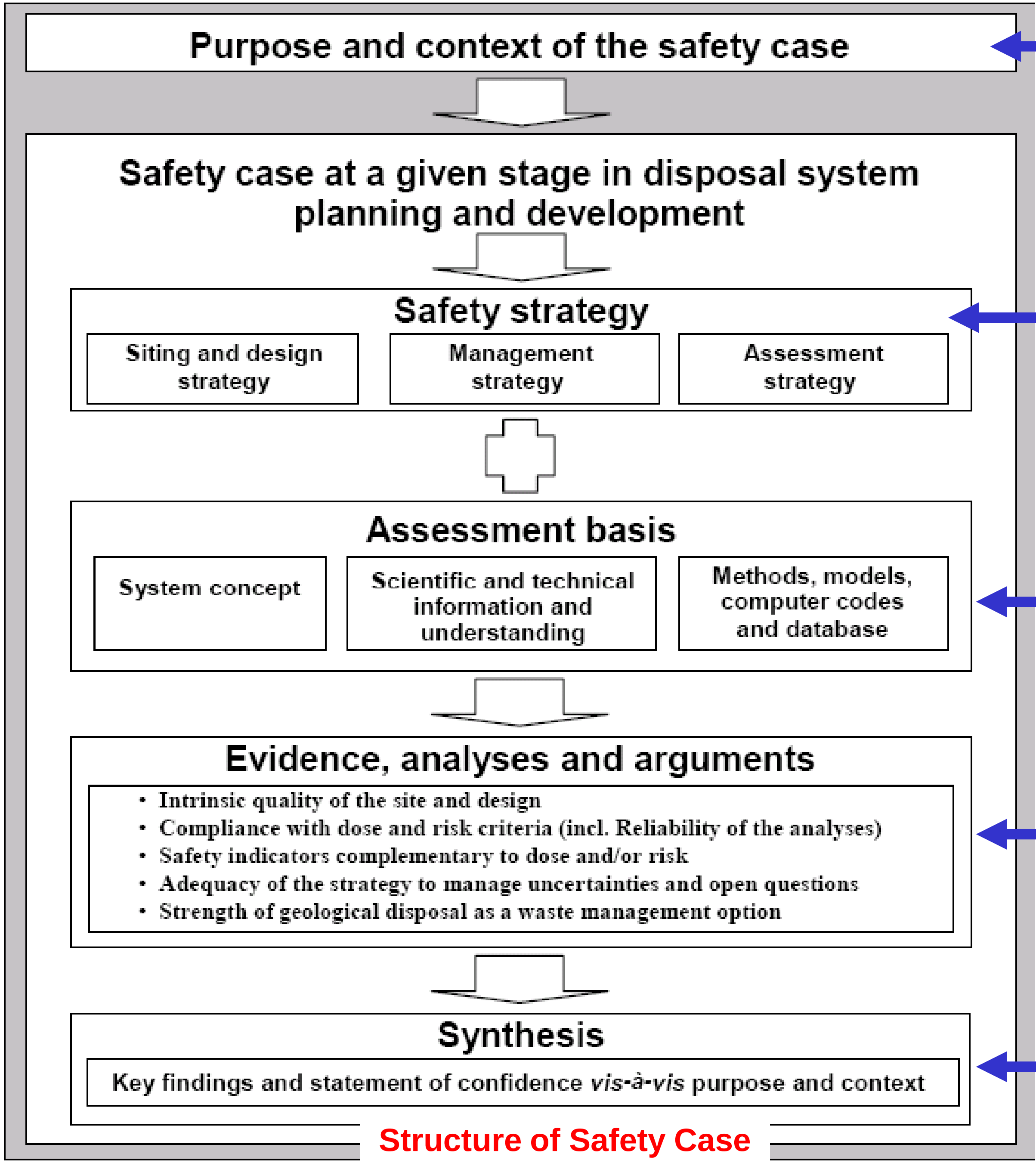
The most important resource of any radwaste organisation is its expert manpower. Specialists can be trained using existing structures, but generalists must be cultured – using a combination of tailored training and focused “on the job” transfer of experience from mentors. Project planning must take this critical goal into account!

Coordination & leadership

- Topics normally found in "project management" handbooks, but taboo in "hard science" projects
- Nevertheless, critical for a project that is pushing the leading edge of technology and is developed with a perspective in the order of a hundred years or so
- Executive coordination is essential to:
  - monitor progress and feedback to ensure that output is appropriate to all users (implementers and regulators, data inputers and outputers, other stakeholders)
  - assure strict quality management, as this will eventually be used to support licensing decisions for repository projects
  - strategy development (given the time frame, needs initiatives to anticipate important future developments in technology or project boundary conditions)

Ensure applicability

- Fundamental role for all users is related to a **safety case**:
  - Developed by NUMO, on the basis of the support provided by knowledge producers
  - Reviewed by the regulators and particular stakeholder groups, facilitated by the agreed structures and databases that the KB contains
  - The focus for discussion with other stakeholders and decision-makers, who can access supporting information in as much detail as they desire



Structure of Safety Case – NEA 2004

User-specific

Summarised in the NSA: 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

Stepwise evolution of the Safety Case to support site selection decisions

Site-specific safety cases

Safety confirmation through intermediate SC reviews

H12 SC generic → SC for PIA selection → SC for DIA selection → SC for site selection → SC for licensing → → → SC for closure

Changes:
• technical
• regulatory
• socio-economic

Changes:
• technical
• regulatory
• socio-economic

Total synthesis:
• technical
• regulatory
• socio-economic

.....

Total synthesis:
• technical
• regulatory
• socio-economic

.....

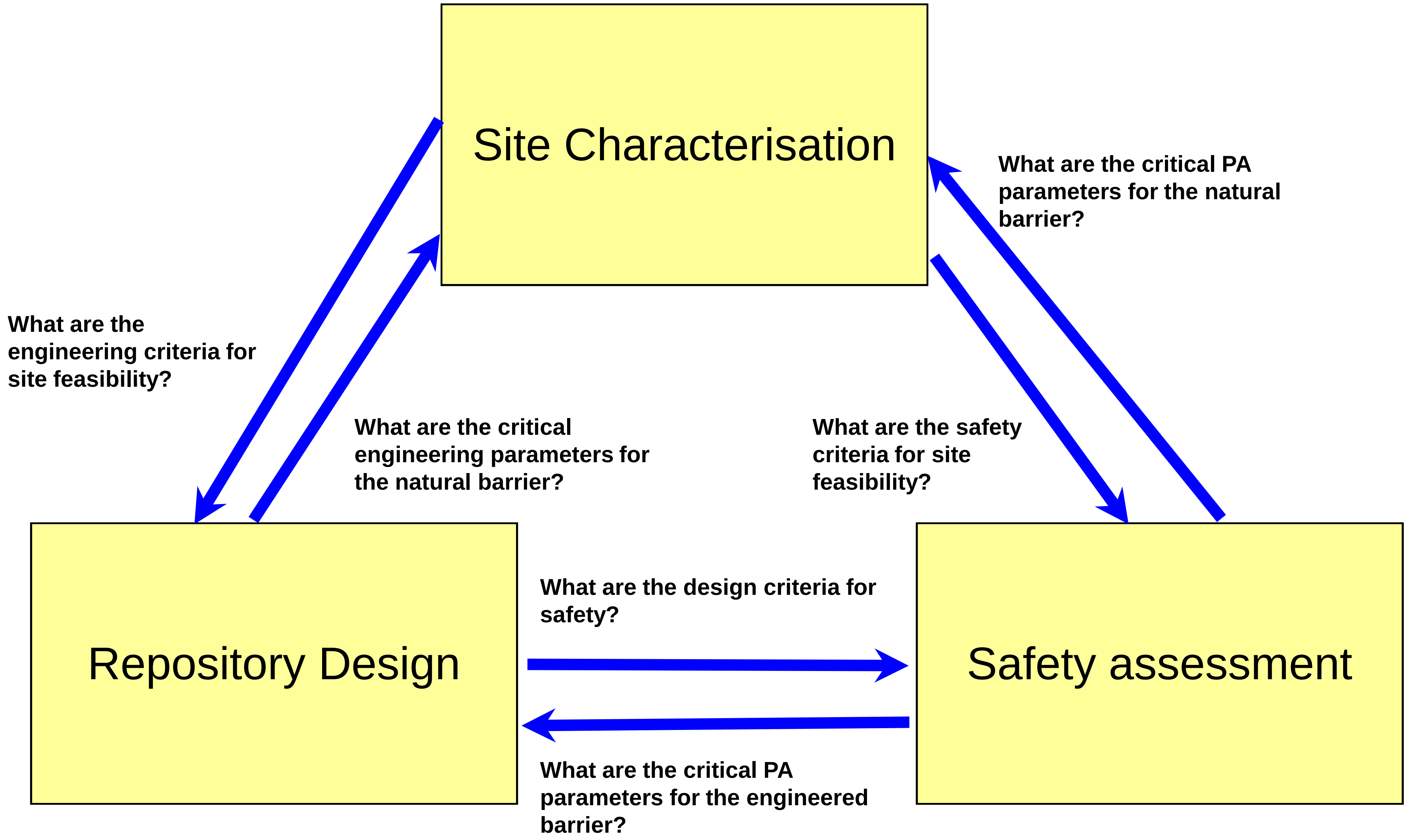
Synthesis of
- site understanding
- site-specific design
- state-of-the-art system understanding

Regulatory constraints:
- goals
- boundary conditions (e.g. timescales, treatment of special scenarios, …)

Socio-economic BCs:
- acceptance
- financial constraints
- ….

The safety cases need to:
- confirm basic site / concept safety
- provide input for site-specific comparison of design options
- provide support for site comparison
- form a transparent record to support licensing

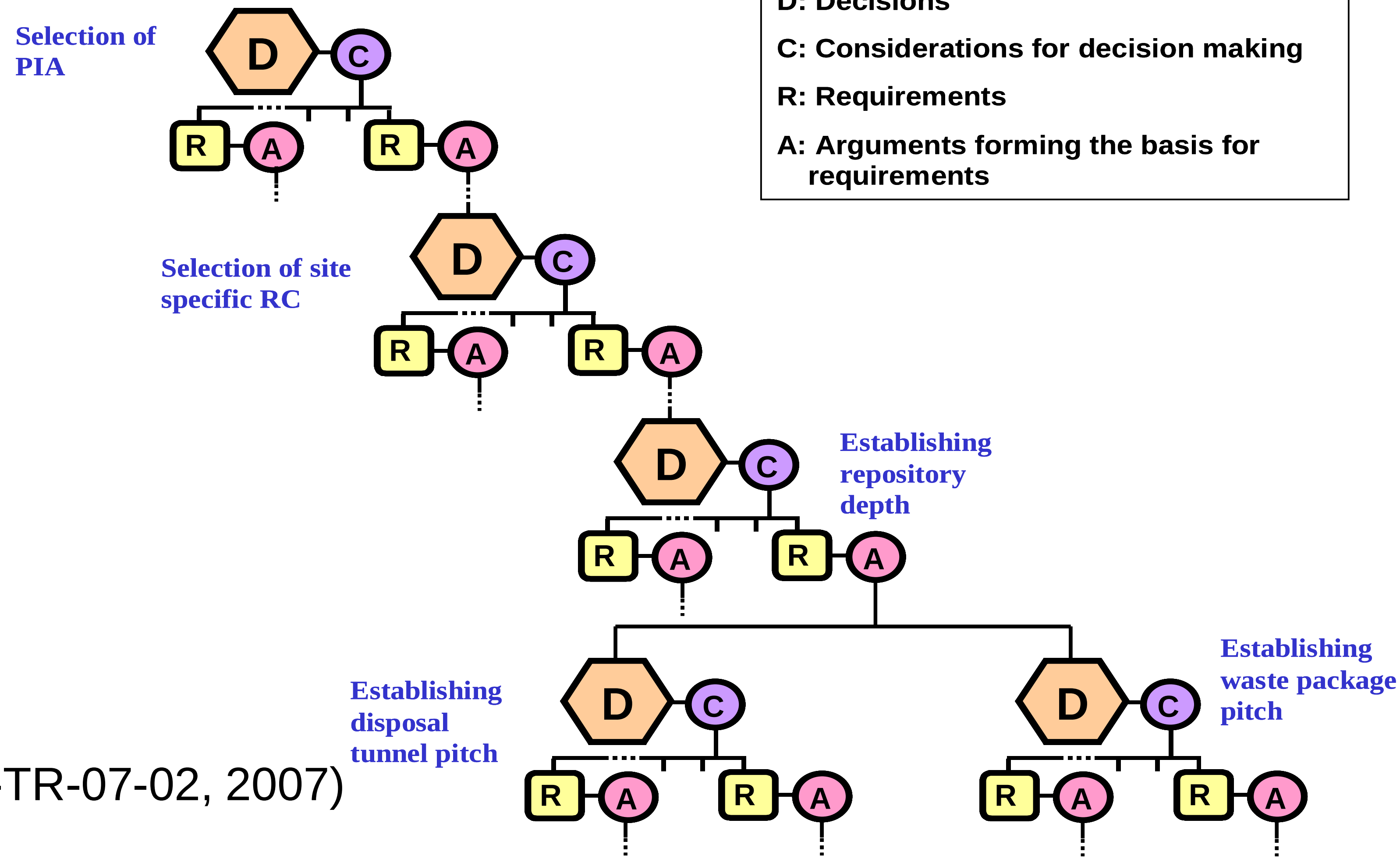
The Goal: coupling of RC / SC/ PA



Practical implementation

- Principles are fine, but tricky to carry out in a transparent manner
- Formalisation of processes and, in particular, the decision-making procedure can explain and allow consensus on the inevitable trade-offs required to develop a programme that balances competing requirements
- General approaches to solution of such problems are known – but few are as complex and multi-dimensional (multi-disciplinary) as radwaste disposal!

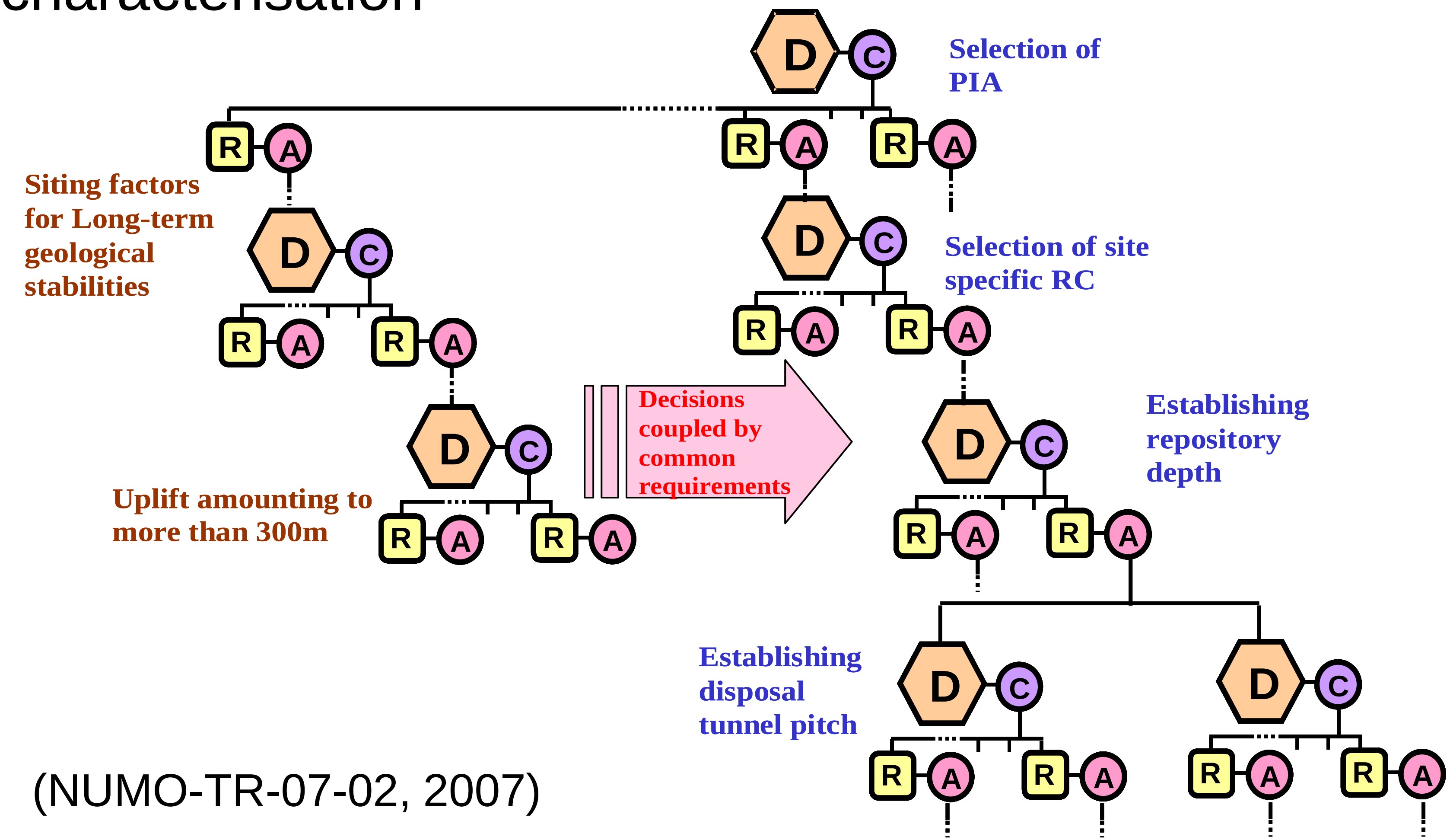
...a requirements management approach is already being developed by NUMO: this needs to be integrated with the KB required to support all decisions



D: Decisions
C: Considerations for decision making
R: Requirements
A: Arguments forming the basis for requirements

(NUMO-TR-07-02, 2007)

...but the tricky bit is when decisions are coupled – difficult even in a simple example with a couple of factors involved, but this may get much more complex when optimising either designs or site characterisation



(NUMO-TR-07-02, 2007)

Big Message (6)

Any KMS development project must have clear applications, deliverables and milestones. The safety case provides a top level focus for all of the work that is carried out in national programmes (NB includes both technical and socio-political issues as defined in Japan) and allows knowledge creation requirements to be prioritised

Quality management

- Agreed to be essential, but has been the bane of many programmes when inappropriately applied
- Can be also be focused by the safety case – level of quality required is related to the contribution to the safety case:
  - High quality required for critical arguments (e.g. dimensions of host rock are well defined)
  - Lower levels acceptable for general supporting information (e.g. Thermal conductivity of overlying formations is characterised)
- When need for QMS can be easily explained, rigorous implementation is more likely to be accepted

Big Message (7)

Quality management must be implemented in a focused and effective manner that encourages all those involved to adopt a quality culture. KM tools should minimise the effort of QA while making benefits clear to users.

Strategic planning – the 100y perspective

- *Planning must focus on key milestones* in the Japanese waste disposal programme *and then work backwards* to identify R&D priorities based on estimated production times (which can be many decades). Such milestones lie 50-100 years in the future and, in order to specify them, the technological – and social – environment at this time must be specified.
- ***Predicting the future is inherently impossible – but approaches used by other industries to scope possible future scenarios will be tested to determine their ability to develop credible scenarios for utilisation in JAEA's projects***.

JAEA Think Tank – JTT – concept (1)

- Development of long-term boundary condition scenarios lies within the realm of Futurology, but a pragmatic option involves the use of a Think Tank, configured to provide optimum input to JAEA's specific requirements. The term "Think Tank" is not well defined and often has negative connotations – but the definition:

"**A group** or an institution **organized for** intensive research and **solving of problems, especially in the areas of technology, social or political strategy**, or armament"

seems appropriate, especially with the emphasis noted

JTT concept (2)

- Criticisms of think tanks often focus on bias or unrepresentative membership. To get around this, we borrow from the concept of Delphi Polls (polling of opinions on an unknown topic from a wide public produces results that cluster around the optimum solution).
- To make this practical, instead of polling a large random sample, we involve a small sample, **specially selected for their demographic, social, academic and cultural diversity** (as developed for modern opinion polls).

Output

- The JTT provided a novel perspective on the planning basis for the KMS
- Even if output must be treated with caution, the approach was certainly valuable in providing a perspective on the timescales over which planning is repository planning is carried out

Big Message (8)

Long-term planning can only be carried out with an appreciation of the inherent volatility of project boundary conditions (both technical and socio-political): exercises such as the JTT can introduce such perspectives to specialists and younger staff.

Critical applications

- Although radwaste management work components are strongly coupled, particular areas are obvious priorities for advanced KMS application
- Geosynthesis is a good example, as the integration of vast amounts of multidisciplinary knowledge, much of it tacit, is essential to plan, implement and analyse the output of modern site characterisation programmes
- This is also a highly sensitive area, where mistakes must be avoided as they are not only potentially very costly, but can also lead to loss of credibility in volunteer sites
- It is also an area where technology is advancing rapidly and data production rates show the exponential growth discussed earlier
- Hence a subsystem that incorporates all the critical challenges that will arise in safety case development

Big Message (9)

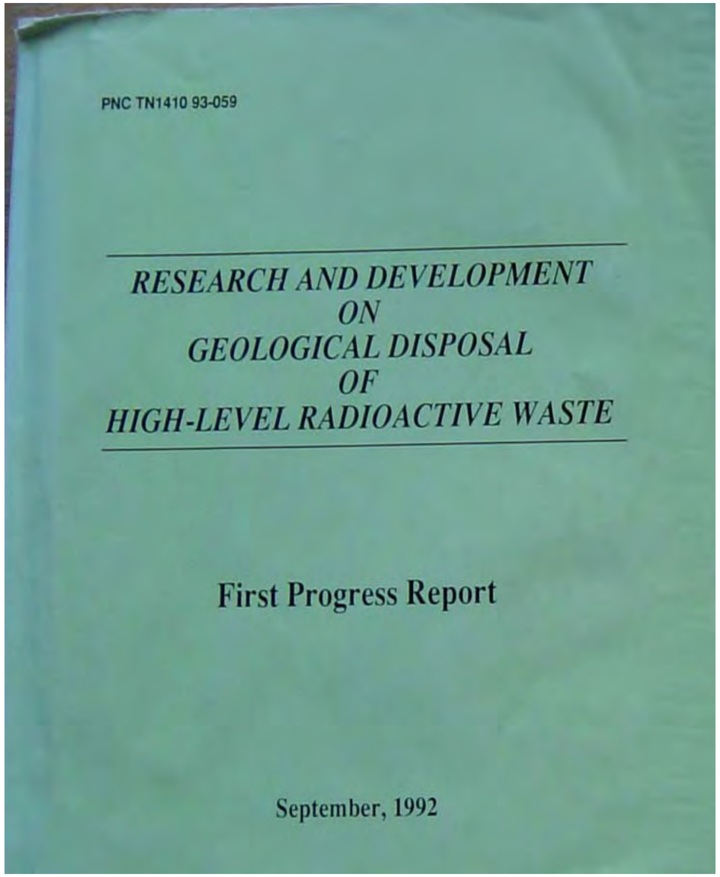
Geosynthesis is selected as a topic for testing of KMS technology, not because it is easier, but because it encompasses all the challenges of application to integrated safety case development within a more restricted topical area.

Synthesis – how do we move forward?

- JAEA must provide a status report on its role to support safety case development in 2010 (H22)
- The KMS will be presented as an essential component of this support function
- Given the problems with the information explosion and our commitment to paradigm shift, we are considering a novel approach to such documentation that illustrates many of the principles previously discussed

The problems of integration & QA (1)

- In the early days, integrated PA was carried out by a small team who had an overview of all project components
- Documentation was in a single report (or a small number of slim reports), split by technical discipline – traditionally: Geology, Engineering and Safety Assessment
- QA was very informal, based on internal or limited external reviews



The problems of integration & QA (2)

- By the end of last century, extensive report series were required to document such projects
- Large reports were produced by teams with little overview of even a single discipline; large amounts of overlap and huge problems in ensuring consistency
- Formal QA introduced, but application limited due to the vast volume of material involved

The solution

- A new approach is required, illustrating how the vast volumes of relevant information can be presented in a user-friendly manner that is accessible to a wide range of stakeholders.
- This should also make quality assurance more transparent and facilitate the complex process of identifying topics requiring future R&D and setting priorities for the use of limited resources.
- Feedback from users will, in turn, be used to improve the structuring of information and the presentation software, so that improved methodology and software tools will be available when they are needed for more critical applications – such as presenting safety cases to support site selection or final licensing of a repository.

The Coolrep idea

The report is produced entirely electronically and is provided on DVD or on the internet in the form of a short, easily readable overview (30 – 50 pages) with extensive hyperlinks to:

- Supporting text providing more detailed technical input
- Full text of key references
- Visual support material, including videos and animations
- All review and QA material
- Relevant web sites

Advantages

- The overview can focus on logical presentation of the safety case; technical support information is accessed where relevant rather than being isolated in a specialist report
- Technical depth can be increased by nested hyperlinks
- Wherever possible quality is assured by direct linking to peer reviewed text
- During production, a single read-only master exists containing the accepted updated draft; amendments of components may be produced in parallel, but contain digital signatures of the author and are added only after acceptance and digital signature of the report coordinator (assures implementation of the QM system and prevents different versions of databases being used by different groups)
- Test version is operational in a web site, allowing interactive features to be developed and demonstrated

Big Message (10)

JAEA will “put its money where its mouth is” in the next status report (H22), which will not only describe the key KMS concepts required for next generation safety cases but also incorporate these in the document itself.

Conclusions

- A novel challenge for KM is to provide a common scientific and technical basis for all stakeholders in the HLW disposal programme.
- Development of the KMS is a challenge in itself. It seems feasible, however, using state-of-the-art IT and organisational KM tools.
- The KMS tools would free more time for – and ease the process of – top-level synthesis and decision-making, which is essential to efficient, safe, and acceptable repository projects.
- The staff implementing and regulating 21st century radwaste projects will thus have a global overview provided by advanced software, databases and interfaces.
- The challenges will be great but, as this is a concern to all national waste management programmes, it is clearly an area where international collaboration could yield major dividends.

The JAEA KMS:
Design and Development, with Emphasis on Geosynthesis

Workshop to Review the Progress of the Development of a Knowledge Management System (KMS) and an integrated Information Synthesis and Interpretation System (ISIS)

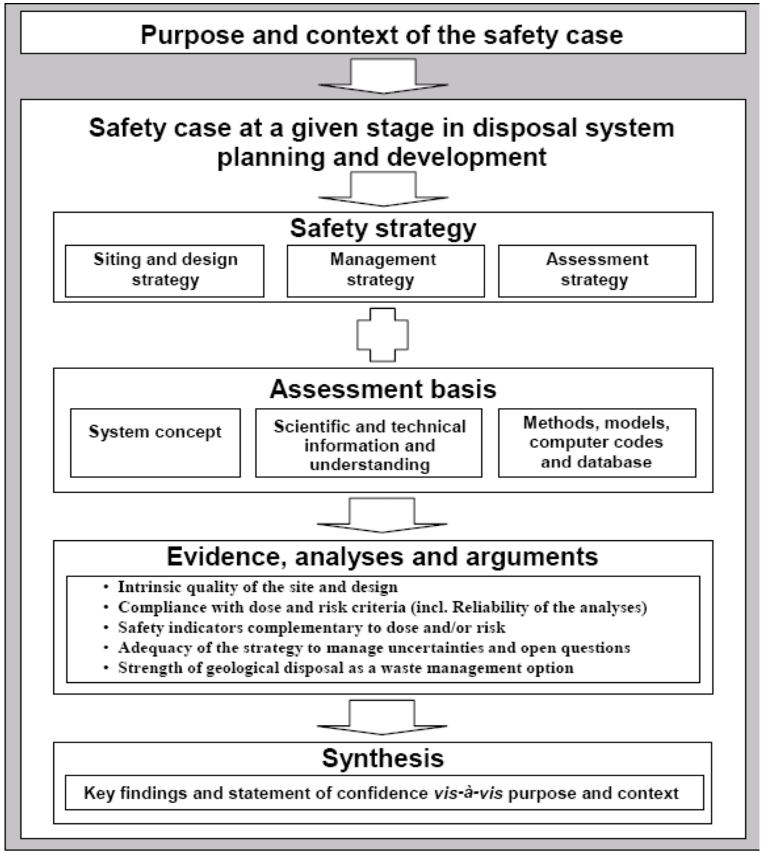
11-12 November, 2008
Tokyo

Kazumasa Hioki

Refining the Safety Case: emphasis on pragmatism and providing focus for the R&D program

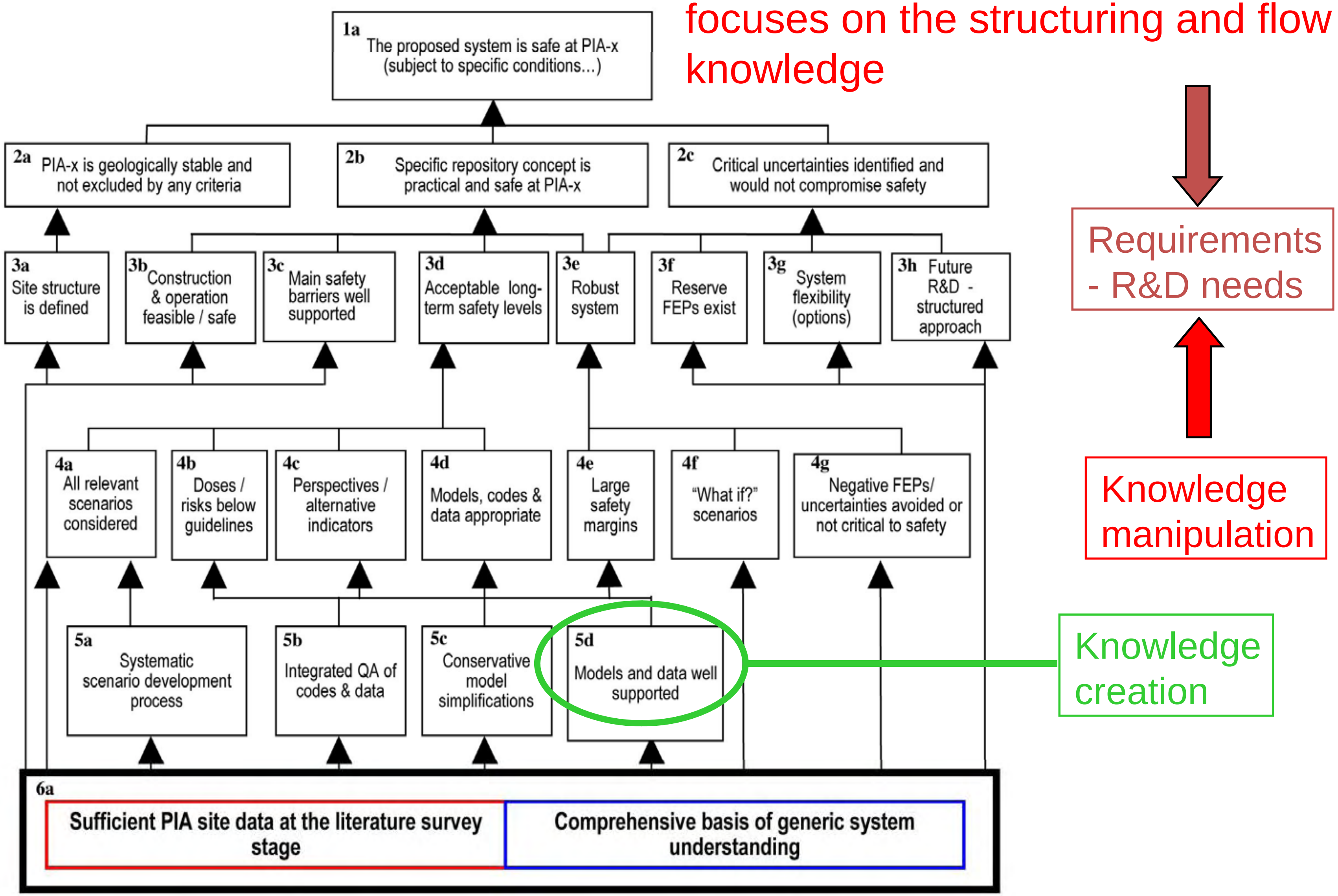
The Safety Case in context

- Demonstration of safety requires more than conventional performance assessment, hence widespread use of "Safety Case"
- Emphasis to date is on post-closure safety; as repositories move closer towards implementation, more aspects need to be considered
- In real life, trade-offs are needed between factors influencing operational safety / practicality, post-closure safety, cost, environmental impact, etc.
- Benefits in widening the definition of "Safety Case" to explicitly account for all the issues to be considered when decisions associated with repository siting or design are made

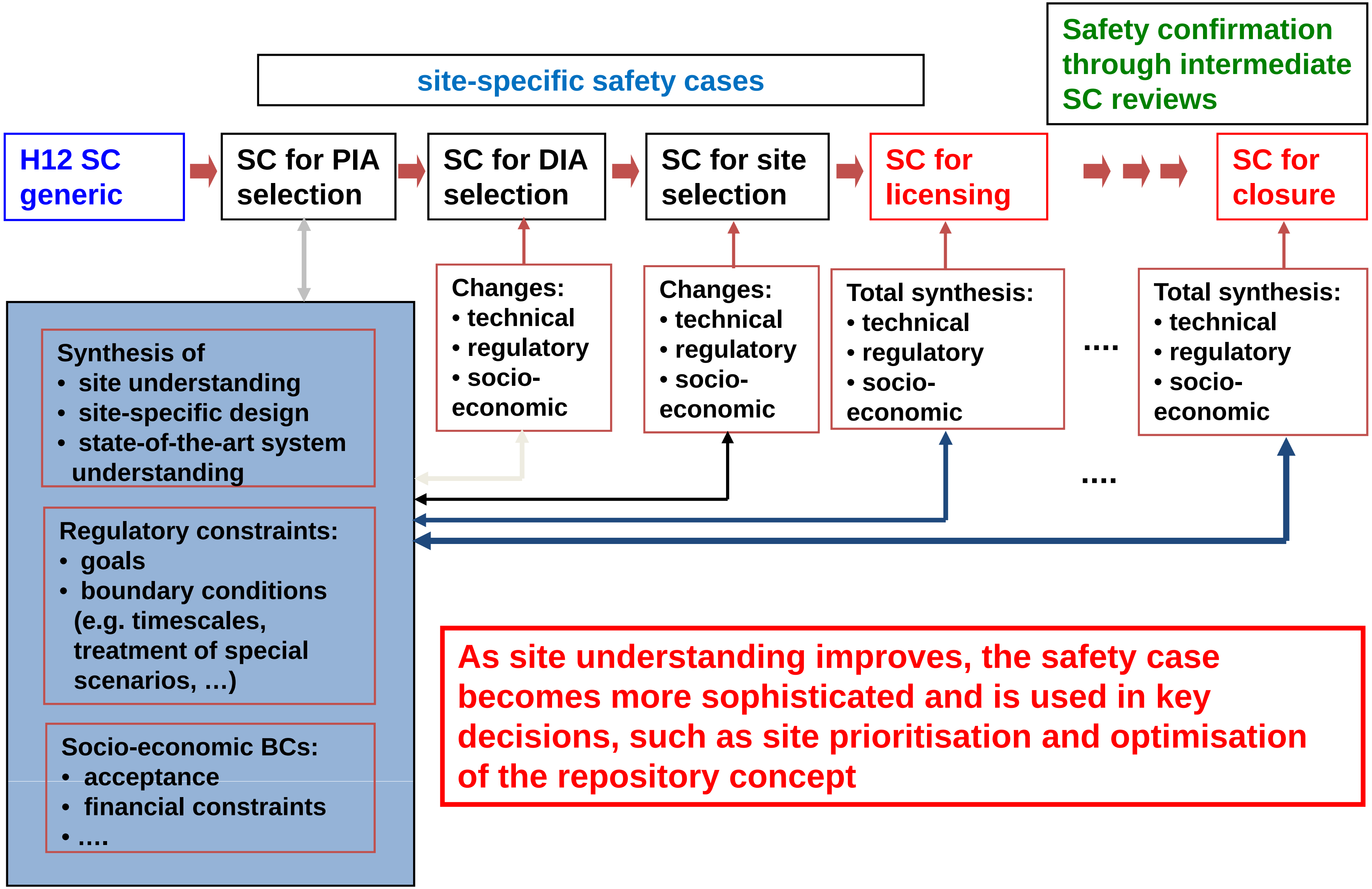


Safety Case – knowledge flows

An alternative representation, that focuses on the structuring and flow of knowledge



Stepwise evolution of the SC to support site selection decisions

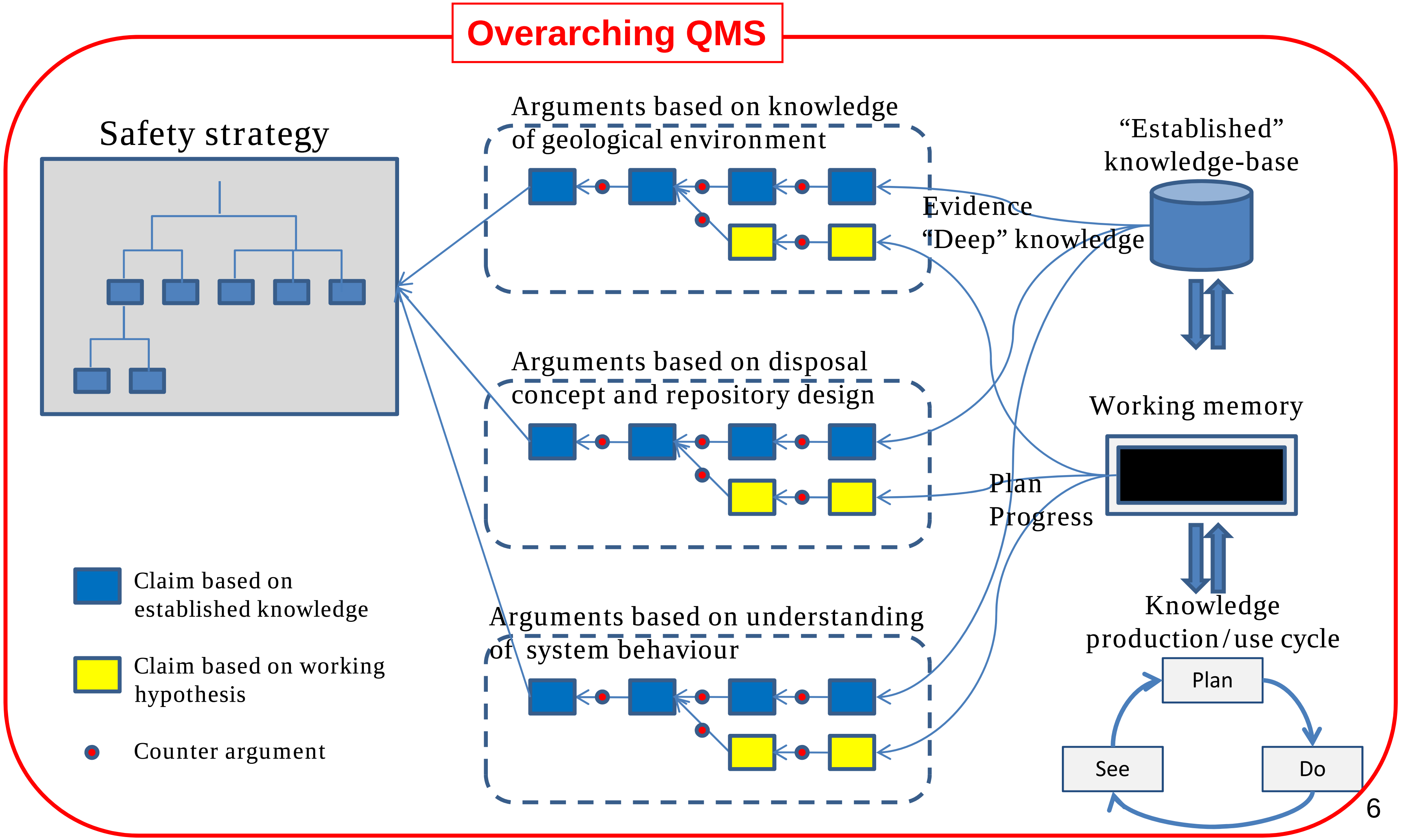


As site understanding improves, the safety case becomes more sophisticated and is used in key decisions, such as site prioritisation and optimisation of the repository concept

Safety case as an argumentation network

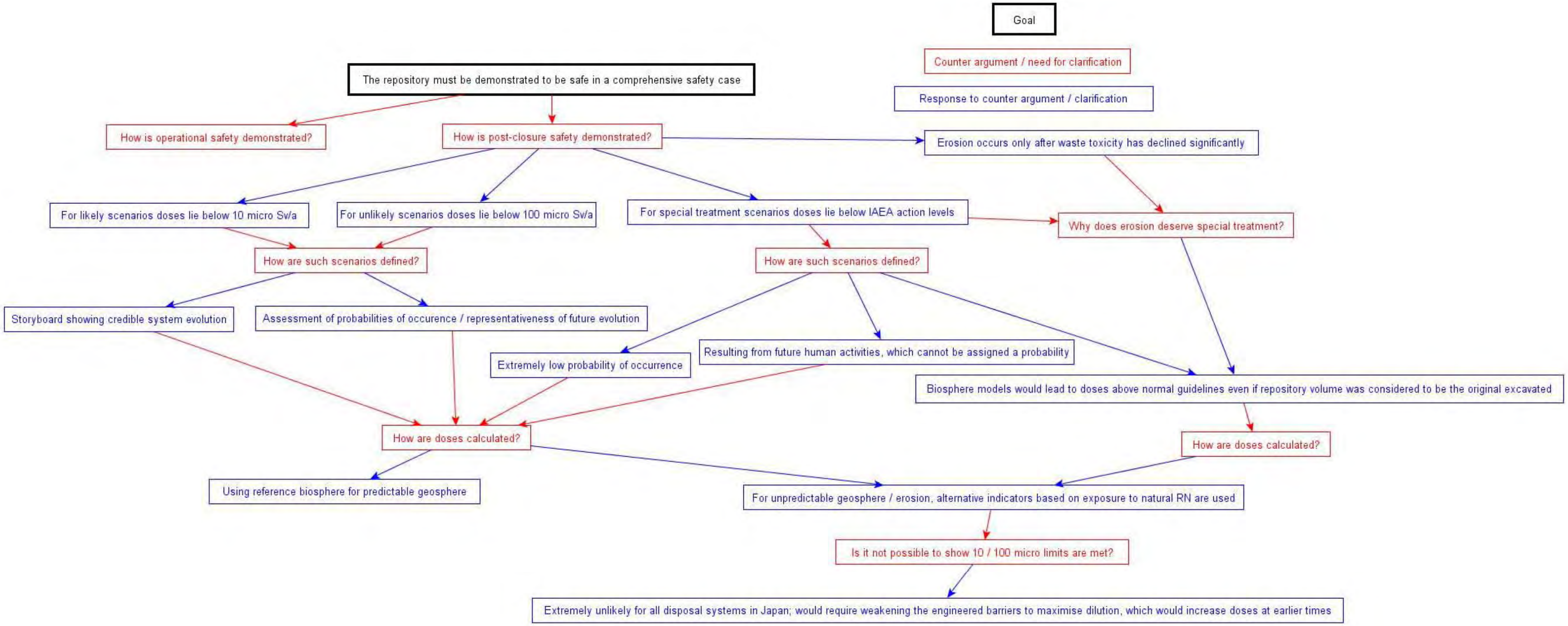
- Evolution of a safety case is an iterative process, reflecting growth of the “knowledge base”
- The dialectic nature of this process can be effectively represented as an argumentation network
- Safety case in each phase should
  - Integrate best available knowledge
  - Contain established knowledge but acknowledge gaps in understanding at early times
  - Keep flexibility in repository concept to counter-balance “surprises” in site characterization or associated R&D
- Key arguments are supported by multiple lines of evidence
- Tight deadlines and limited manpower require utilization of the best and most efficient knowledge management tools available
- Because this safety case may eventually be used to support a license application, knowledge must be quality assured

"Evolving" argumentation model



Argumentation networks

Various software tools facilitate development of argumentation networks that capture the thinking associated with the fundamental claim that “a specific repository is safe”

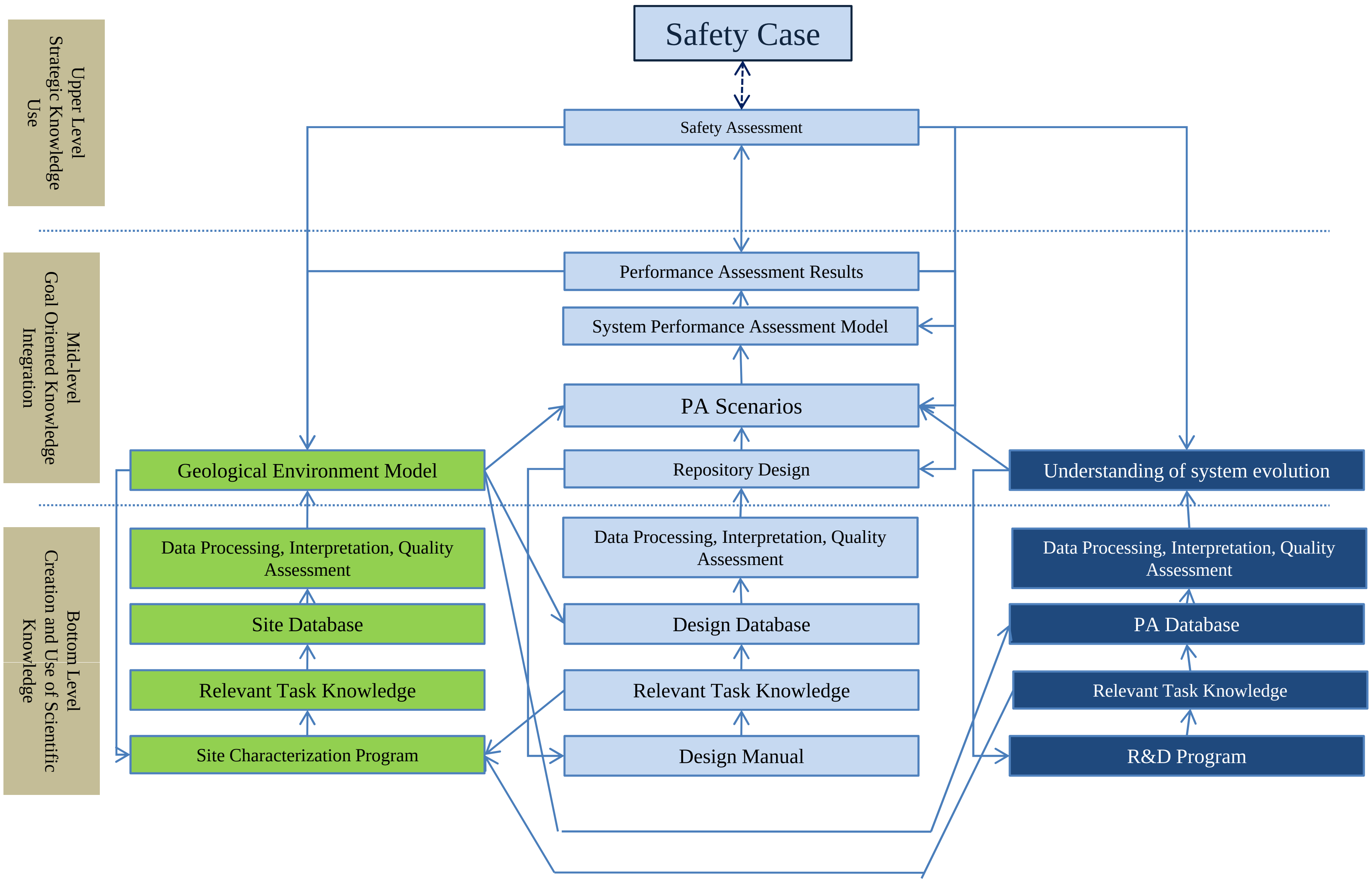


How can a KMS improve the safety case?

- Development of hierarchy of requirements and argumentation networks
  - Determine requirements and threats
  - Use argumentation schemes to structure and ensure completeness
- Use of established knowledge
  - Find multiple pieces of evidence to support claims in knowledge base
  - Provide network of “deep” knowledge to help understanding arguments
- Link with R&D program planning
  - Focus on identified safety-critical issues and open questions
  - Real time updates rather than the snapshot of a conventional report
  - Demonstration of readiness for “surprises”
- Communication
  - Interaction
  - Flexible presentation based on needs of particular audiences
  - Use of all modern media

Focusing Knowledge Creation: escaping from bottom-up R&D programs

KMS in knowledge creation and use



Top-down R&D management

- A general problem is that top-level management have no deep understanding of critical technical areas, hence past R&D programmes have a large bottom-up drive from experts who understand the topic involved
- The Safety Case argumentation networks provide an easily understood method of placing even very technical projects in the context of the deliverables required to support the contention that a repository at a specific site is safe – not only helping to set R&D priorities, but also helping Knowledge Producers understand the requirements and constraints on their work

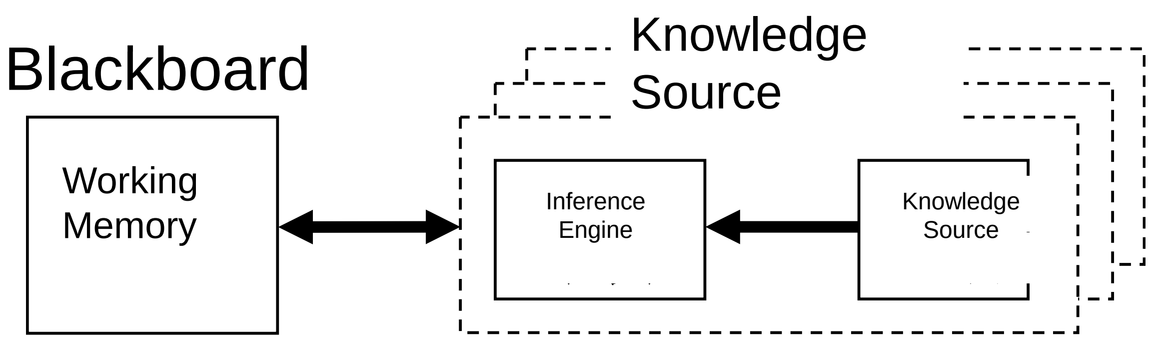
Selecting & applying tools: avoiding re-invention of wheels by customising established KE technology

Key challenges for KMS development

- Problem 1: How can the production and use of various knowledge in diverse fields be systematically managed?
    - Solution ⇒ Blackboard Architecture
- Problem 2: How can all geological environment assessments and surveys be made intelligent?
    - Solution ⇒ Hybrid Knowledge and Information Systems
- Problem 3: How can multiple, diverse expert systems be developed efficiently and have their quality controlled?
    - Solution ⇒ Expert System Development Tools within a strict QMS
- Problem 4: How can the large amount of specialist knowledge of diverse disciplines be efficiently and systematically acquired and organized?
    - Solution ⇒ Formal Knowledge Acquisition Methodology (Problem Solving Method)

Blackboard Architecture

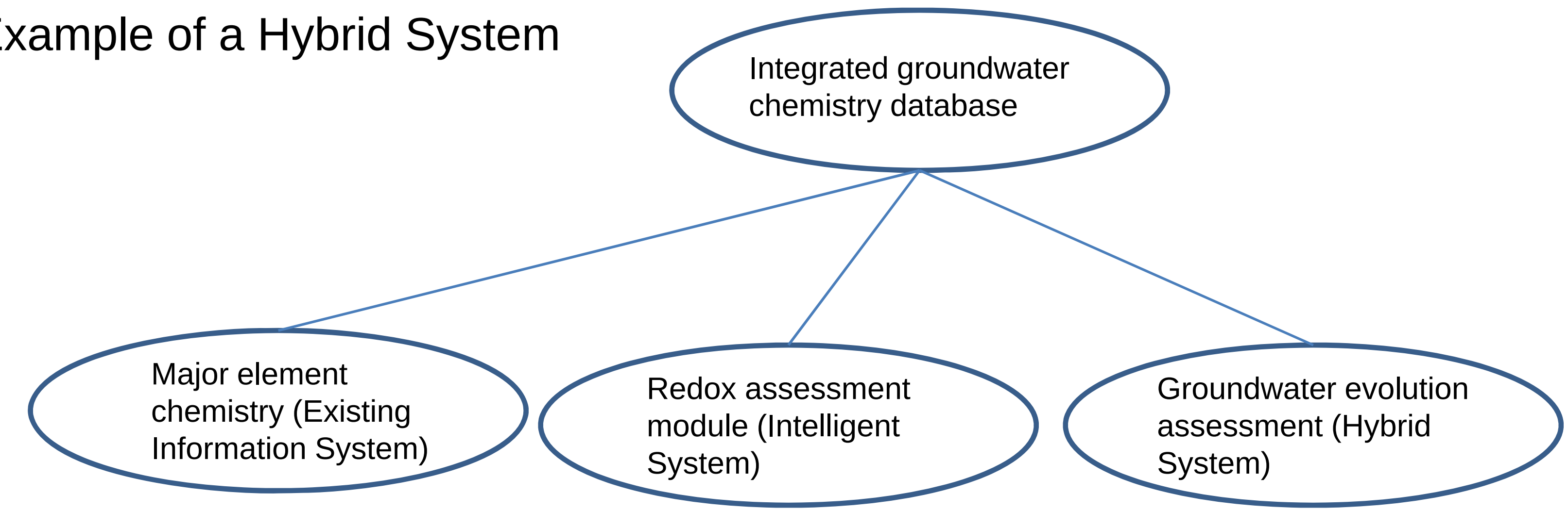
- Problem Solving Model for Scholastic Organizations
- Organizes and displays a shared space where members of a group can view the results of the tasks of individual members and facilitate group cooperation.
- Benefits of using Blackboard Architecture:
  - Provides a problems solving framework based on knowledge integration.
  - Presents a hierarchical structure to express diverse, interrelated knowledge.
  - Aids application of inference engines and other knowledge engineering tools.
  - Offers improvements in development efficiency and maintainability when compared to a single, large-scale knowledge base.



Hybrid Information/Intelligent Systems

- Systems that combine automated knowledge production by intelligent systems and areas in which staff use existing information systems to process information.
  - Existing information systems fulfill specific pre-defined functions on shared data groups stored in a certain location (a database) on the basis of procedural knowledge.
  - Intelligent systems are designed to produce new information using declared knowledge and some kind of inference mechanism.

Example of a Hybrid System



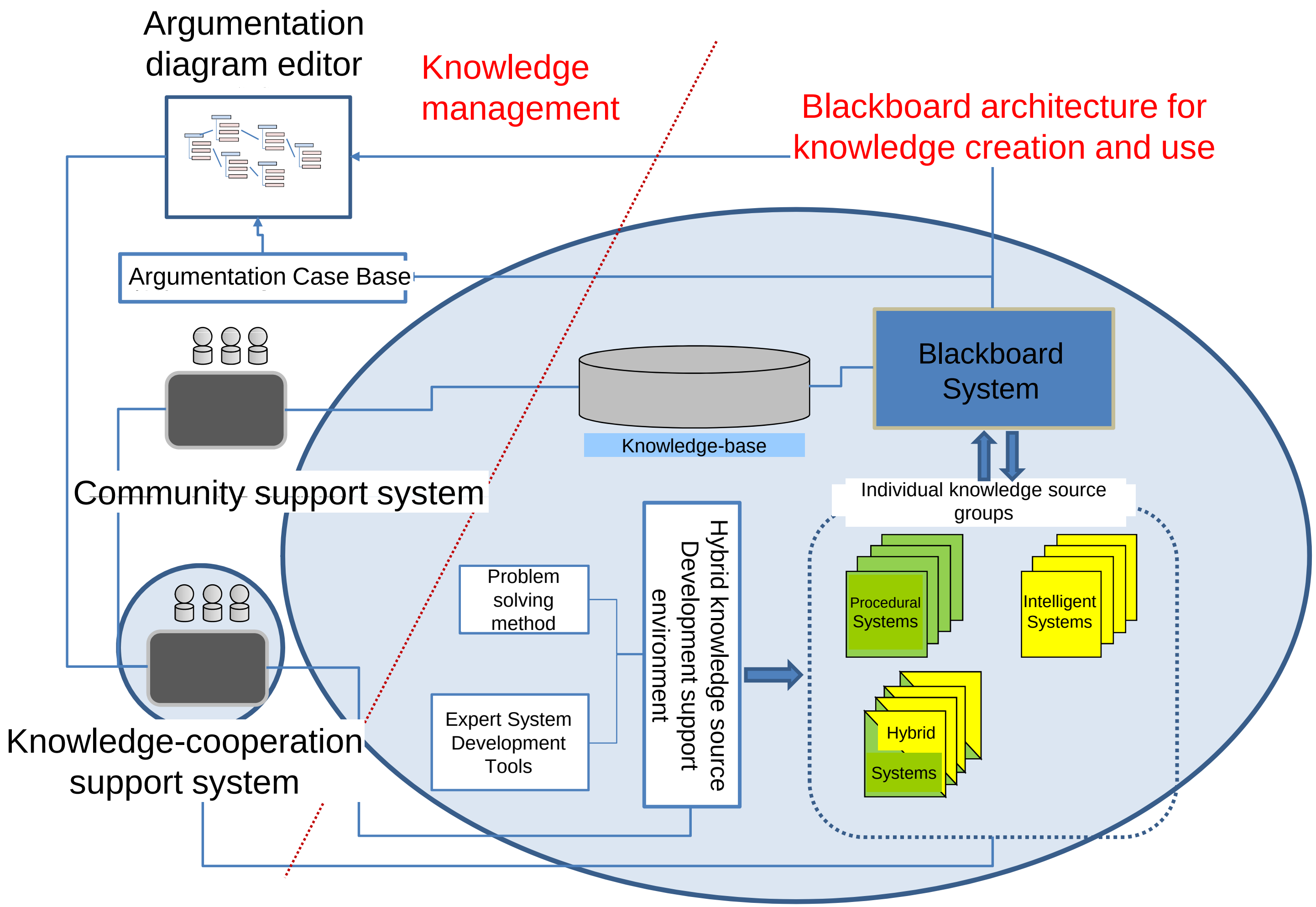
Expert system development tools

- Types of Tools
  - Programming Languages (Procedural/Declarative)
    - Flexibility is highest.
    - Development time is longest.
  - Expert System Shells (Ready-made ES templates without a KB)
    - Have highest flexibility
    - Development time is shorter
  - Expert System Development Environments
    - Flexibility is low: in particular unsuited to non-routine development such as research development
    - Development time is even shorter
- Selection Criteria
  - **When choosing between these options you should use a shell where you can, an environment when you should and a language only if you must**.

Use of formal Problem Solving Methods

- This method specifies the necessary knowledge and necessary task sequence for problem solving before constructing an expert system.
- The inference process used by experts to solve problems is called task knowledge. Because it is totally different than the domain knowledge related to the subject, the collection of related knowledge is modeled separately from these processes.
- By modeling expert related problem solving process task knowledge of the general (symbolic) tasks involved in the design, diagnosis, and planning necessary to solve problems, a generic problem solving method not dependent on the subject domain can be constructed.
- The standard PSM library is KADS (Knowledge Acquisition Design System) or its successor CommonKADS. The KADS approach includes the following three knowledge acquisition processes.
  - Elicitation
  - Analysis: Interpreting elicited knowledge
  - Formalization: Expressing the knowledge in a way that can be used by a computer

Structure of the JAEA KMS



Blackboard architecture: a practical method for capturing tacit knowledge for key applications

Background

Borehole drilling is one of the most expensive and safety-critical activities during site characterisation

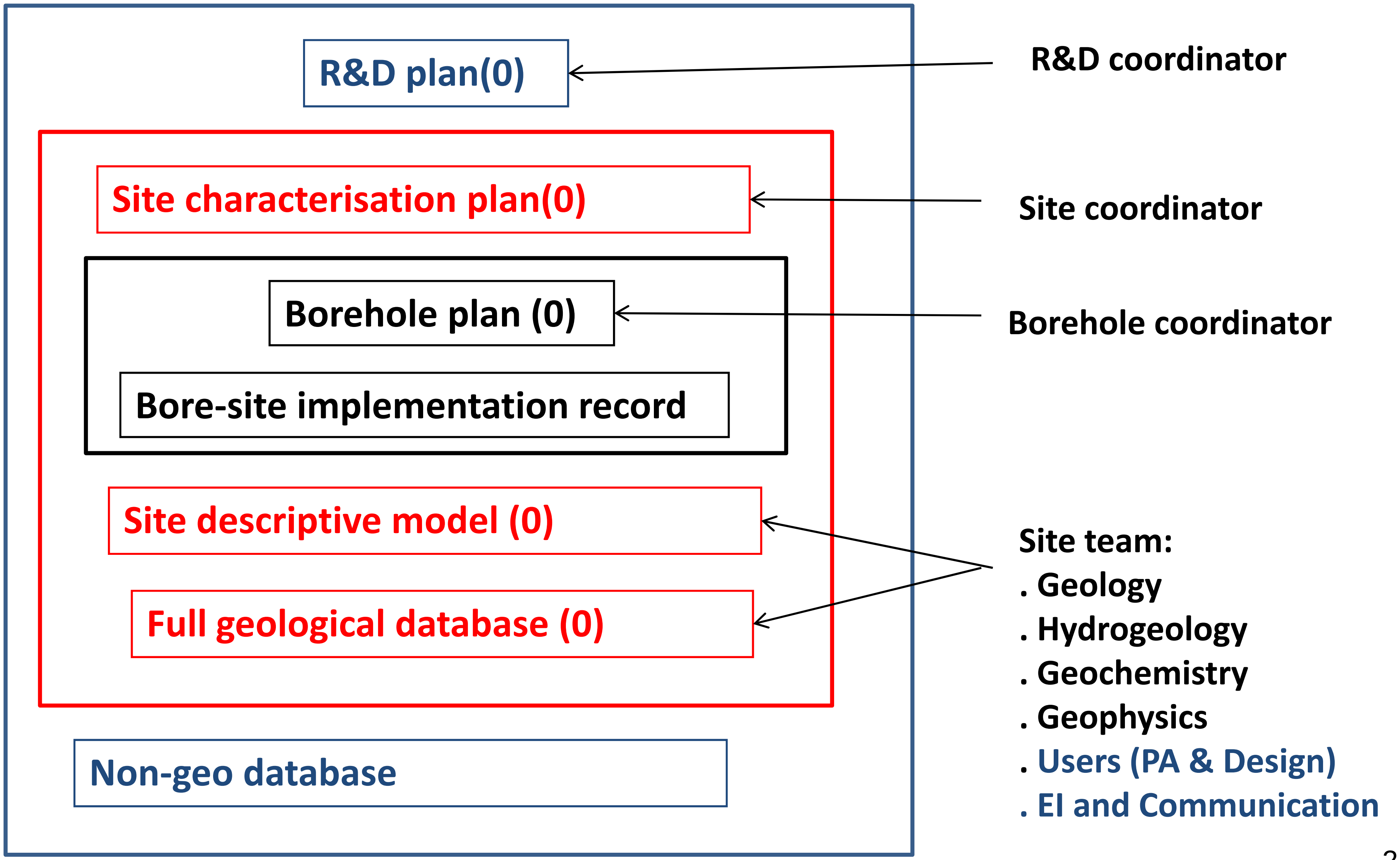
During drilling very large volumes of data are produced; some continuous and some discrete – either raw or processed information

Based on international experience, despite extensive planning, surprises are to be expected

The aim is to support the site team by:

- Distributing information in a processed form that makes interpretation easier
- Helping identify “surprises” and coordinate responses

Starting point for borehole drilling



ISIS borehole blackboard

Borehole data

Primary input data

Borehole plan (t)

Bore-site implementation record

Supporting data

R&D plan(t)

Site characterisation plan(t)

Site descriptive model (t)

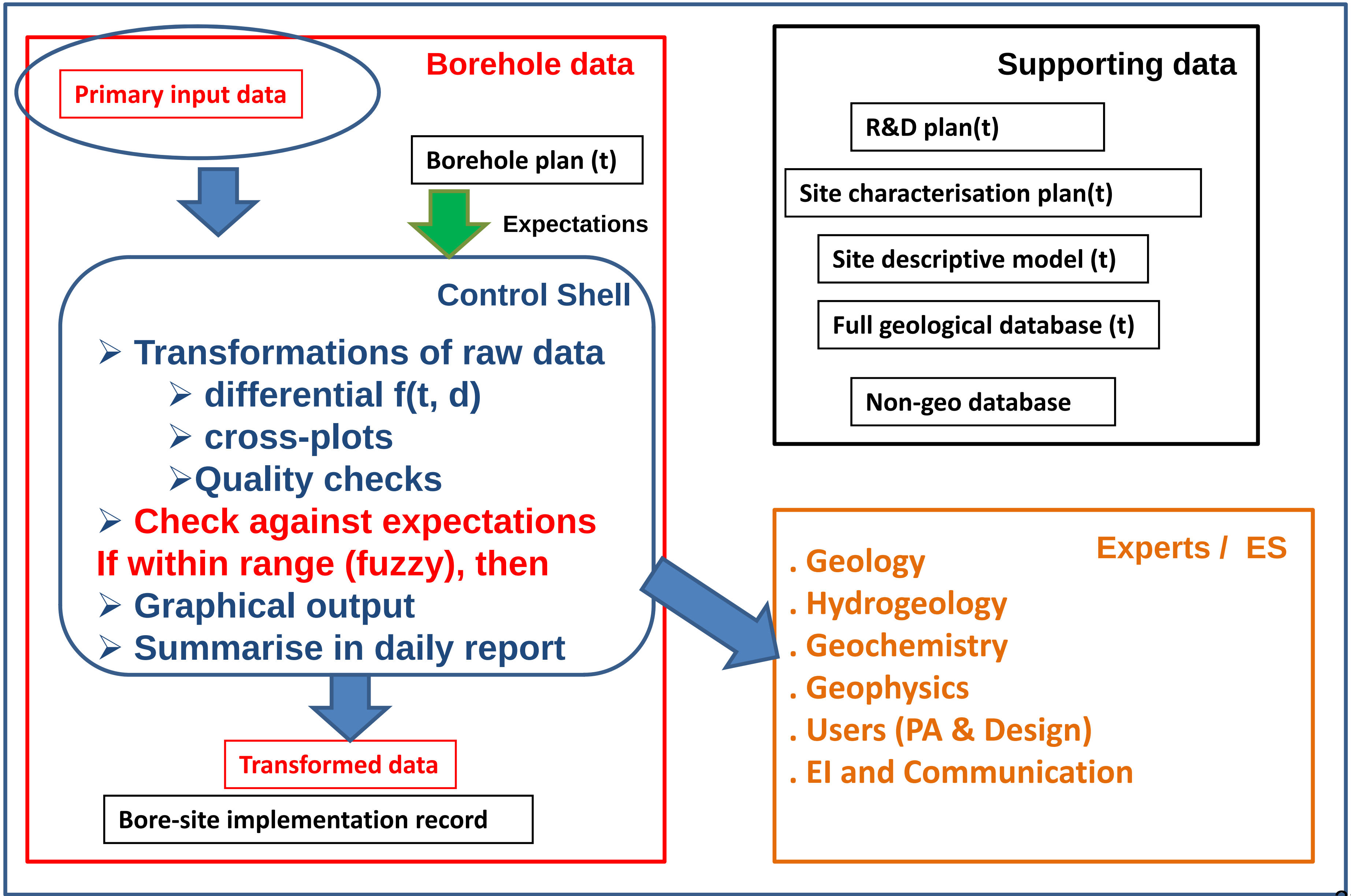
Full geological database (t)

Non-geo database

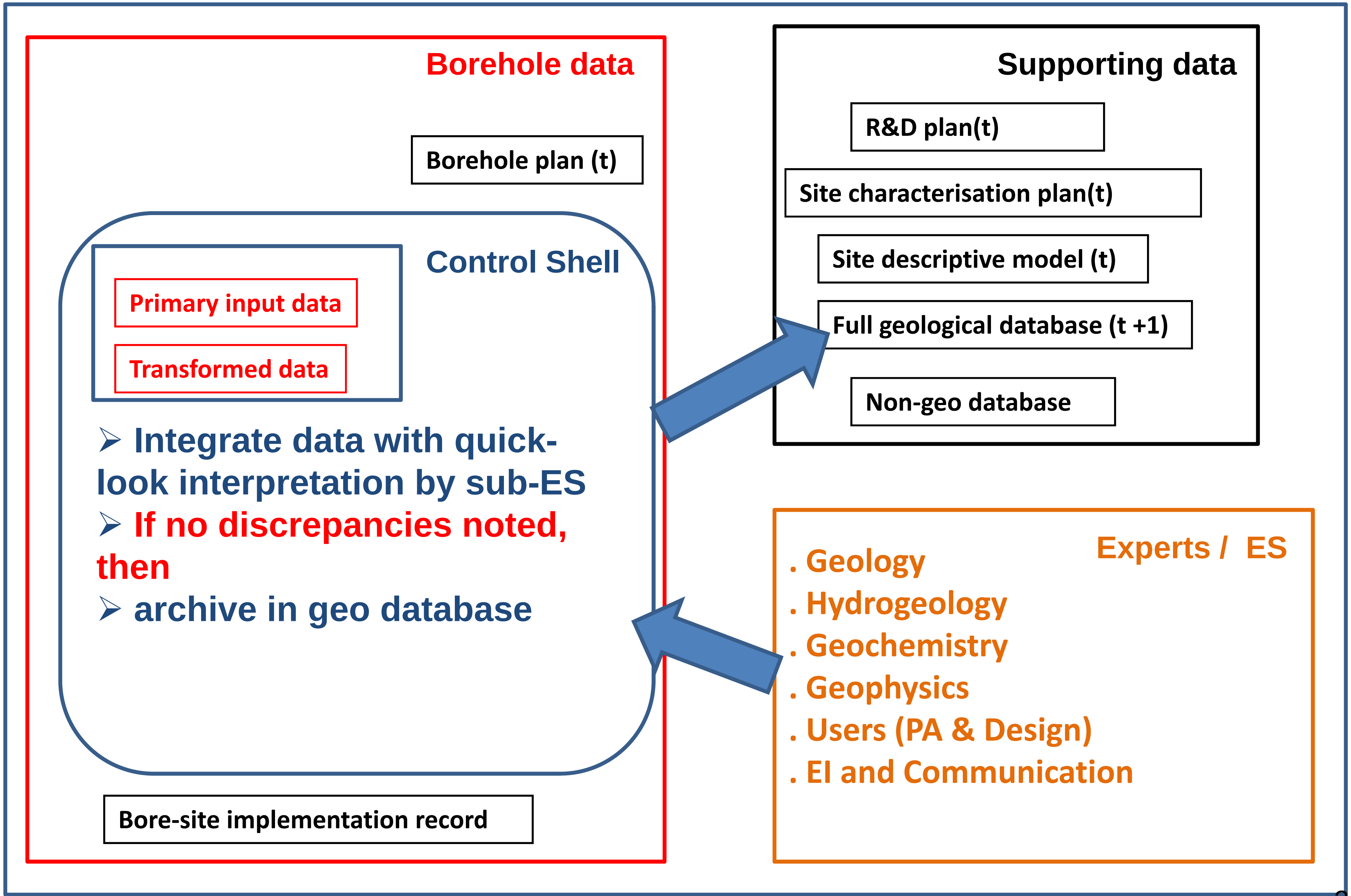
Experts / ES

. Geology
. Hydrogeology
. Geochemistry
. Geophysics
. Users (PA & Design)
. EI and Communication

ISIS borehole blackboard



ISIS borehole blackboard



Responding to surprises

The case previously illustrated would correspond to the 1-way flow indicated in the RWMC-geosynthesis system: more critical is the case when something unexpected occurs

Surprise events can be classified as

- Alarms – signals that indicate danger
- Anomalies – signals that indicate that the progress in drilling is not as expected
- Discrepancies – incompatibilities of signals indicating potential problems

ISIS borehole blackboard - alarm

Borehole data

Primary input data

Borehole plan (t)

Expectations

Control Shell

- Transformations of raw data
  - differential f(t, d)
  - cross-plots
- Check against expectations

If alarm indicated, then

- Immediate warning to borehole team: recommendations to coordinator
- Log responses

Record of actions

Bore-site implementation record

Supporting data

R&D plan(t)

Site characterisation plan(t)

Site descriptive model (t)

Full geological database (t)

Non-geo database

Experts / ES

. Geology
. Hydrogeology
. Geochemistry
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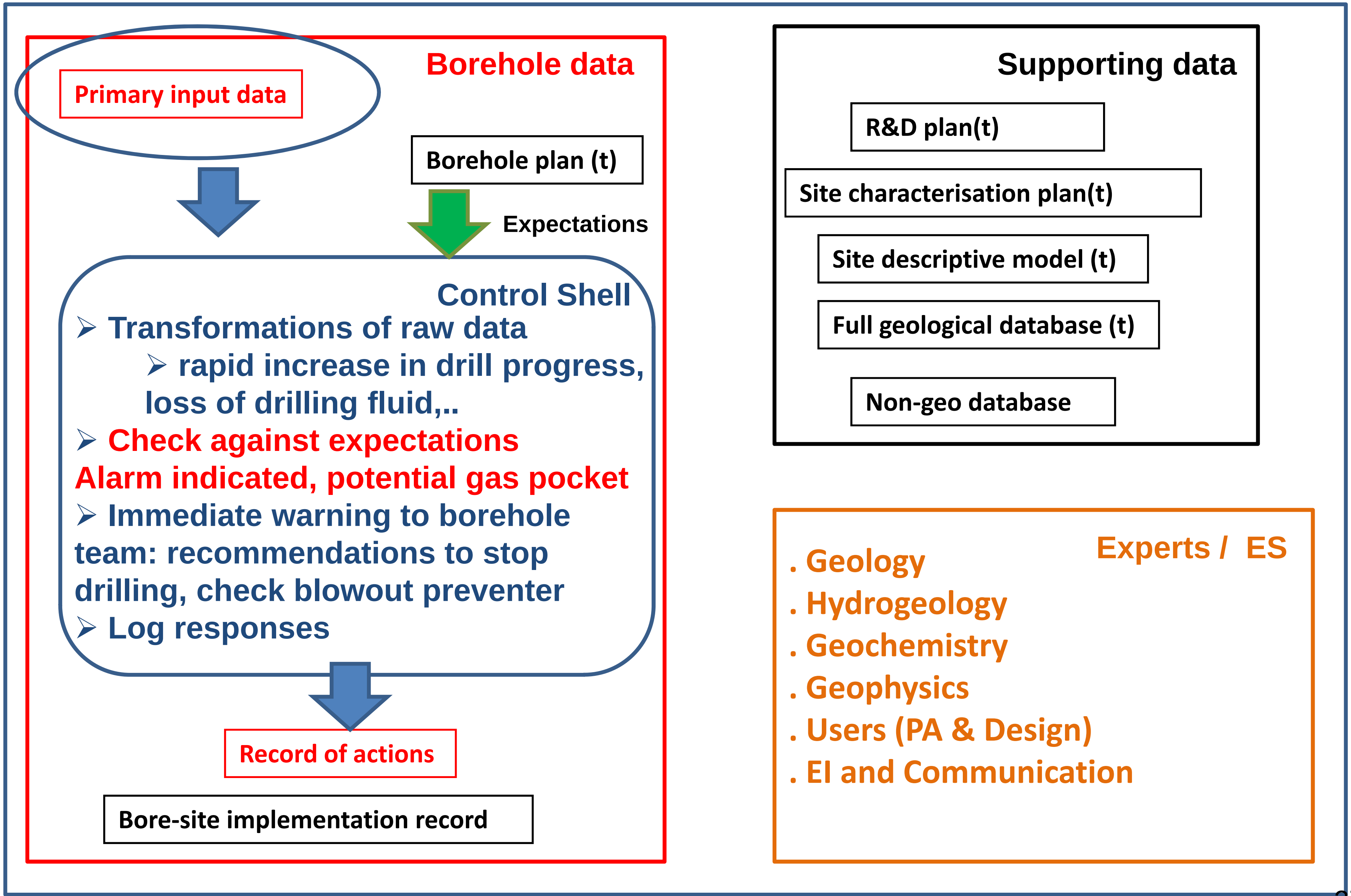
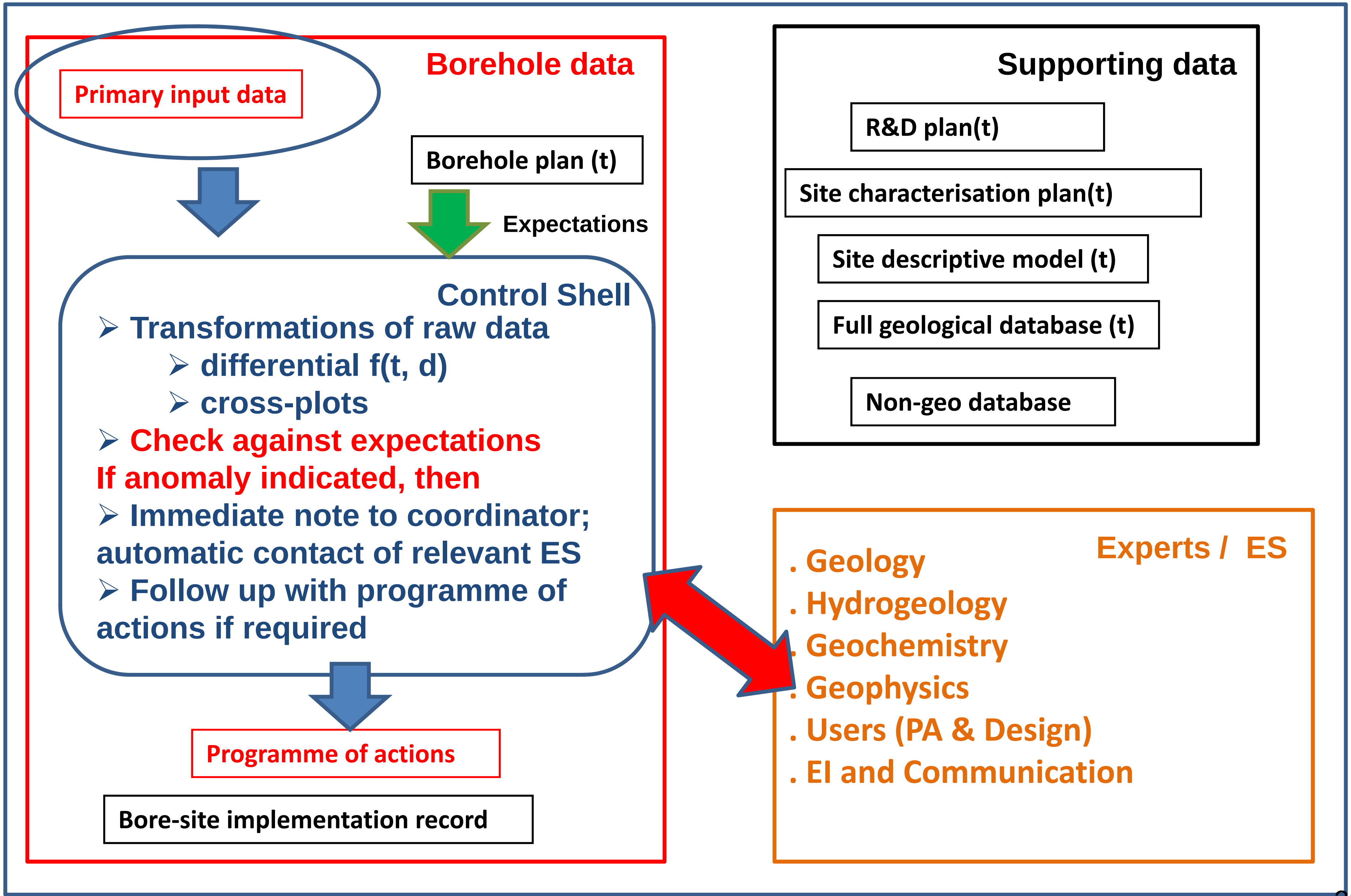
. Users (PA & Design)
. EI and Communication

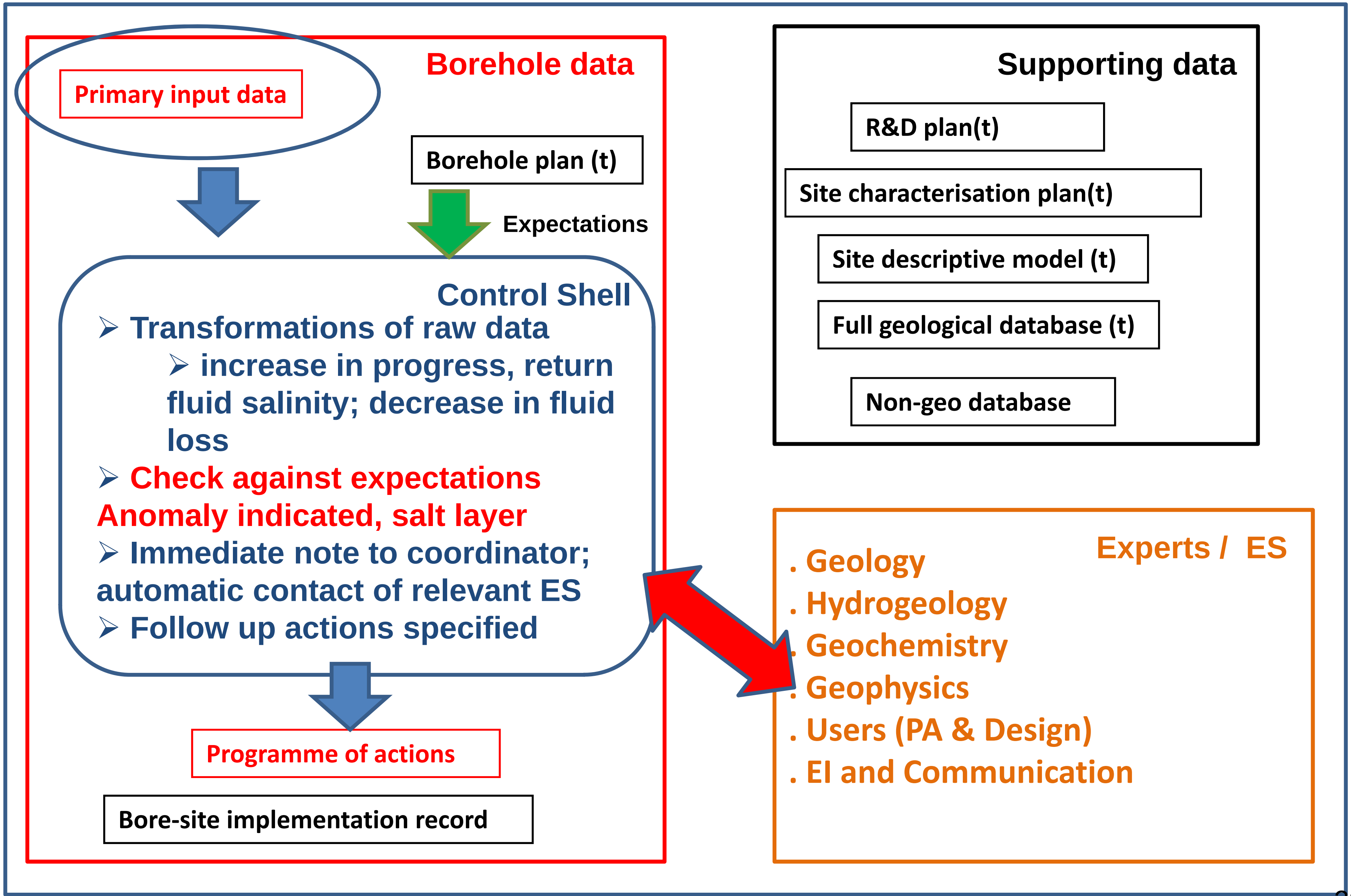
ISIS borehole blackboard – alarm (example)



ISIS borehole blackboard - anomaly



ISIS borehole blackboard – anomaly (example)



ISIS borehole blackboard – anomaly (example)

Borehole data

Borehole plan (t+1)

Control Shell

- Follow up actions:
  - change bit, drilling fluid
  - check geophysics to assess possible thickness
  - modify testing and logging programme
  - modify site model
  - modify site characterisation plan
- Record all actions and archive

Record and archive

Bore-site implementation record

Supporting data

R&D plan(t)

Site characterisation plan(t+1)

Site descriptive model (t+1)

Full geological database (t+1)

Non-geo database

Experts / ES

. Geology
. Hydrogeology
. Geochemistry
. Geophysics
. Users (PA & Design)
. EI and Communication

ISIS borehole blackboard - discrepancy

Borehole data

Primary input data

Borehole plan (t)

Expectations

Control Shell

- Transformations of raw data
  - differential f(t, d)
  - cross-plots
- Check against expectations

If discrepancy indicated, then

- Immediate note to coordinator; recommendations
- Log responses

Record of actions

Bore-site implementation record

Supporting data

R&D plan(t)

Site characterisation plan(t)

Site descriptive model (t)

Full geological database (t)

Non-geo database

Experts / ES

. Geology
. Hydrogeology
. Geochemistry
. Geophysics
. Users (PA & Design)
. EI and Communication

ISIS borehole blackboard – discrepancy (example)

Borehole data

Primary input data

Borehole plan (t)

Expectations

Control Shell

- Transformations of raw data
  - pH of return fluid constant despite varying rates of loss
- Check against expectations

Discrepancy indicated – sensor failure

- Immediate note to coordinator; recommendation checking sensor
- Log responses

Record of actions

Bore-site implementation record

Supporting data

R&D plan(t)

Site characterisation plan(t)

Site descriptive model (t)

Full geological database (t)

Non-geo database

Experts / ES

. Geology
. Hydrogeology
. Geochemistry
. Geophysics
. Users (PA & Design)
. EI and Communication

Control shell components

Data transformation and presentation unit (database manager)

Data trend assessment unit (Rule based ES, with fuzzy components): focused on key data identified by experts / case studies

Neural network examining full raw data set, conditioned by processed data / interpretations (output used by control shell ES)

NB separated from technical ES for specific technical areas, so can be developed independantly

QM: application where, when and to the extent needed

Quality management

- Can be prioritised by the safety case – level of quality required is related to the contribution to the safety case
- Implementation ongoing at several levels:
  - Technical level – QA workshops and implementation programme for URL field work
  - Integrated completely into H22 planning (already well established for H12)
  - Testing within geosynthesis test cases
- Recognised to be a challenge to implement within the KMS and will be the focus of a workshop planned for early 2009

Implementation plan:

stepwise introduction with priority for key areas that have greatest problems managing data flows – e.g. geosynthesis

KMS implementation

Needs to have a responsible group at an appropriate level:

– Top management - concerned with top-level requirements (politics, legislation, budget,...)

– **KM group - responsible for management & guardianship of Knowledge**

– Operational staff - more concerned with creation and use of Knowledge

Commitment at all levels is a fundamental requirement

Resources are needed to rapidly develop user-friendly support tools (encourages active support)

Cost / benefit may be optimised by collaboration with international partners

KM staff require to develop experience in knowledge integration as quickly as possible, e.g. via integrated PA, geosynthesis, etc.

Implementation plan

Concentrate on key problem areas – e.g. Synthesis of geological knowledge needed to plan, supervise and integrate the output from site characterisation – "geosynthesis"

Aim to maximise synergy between the specific work areas targeted (transfer of experience, technology, etc.)

Work to the nominal (optimistic) time plan for repository siting to ensure that tools and knowledge bases are available when required

Balance short term need to meet deadlines with long-term requirements for multi-decade databases and experienced manpower

The challenges of geosynthesis

- Site characterisation usually the most expensive and manpower intensive component of a programme prior to initiation of repository construction
- High socio-political sensitivity and hence media visibility – even rather trivial mistakes or accidents can have major consequences
- Provides basis for major decisions that may determine success or failure of a particular program
- Each site provides new challenges and surprises and hence real-time knowledge management is critical

A look to the future: the KMS as a resource for implementers, regulators and other stakeholders

Outline of future developments (1)

Although the principles of the KMS are reasonably well established, the critical challenge is to develop and demonstrate practical applications of the toolkit that clearly show the benefits involved. For site characterisation, the main KM challenge is geosynthesis, but stepwise implementation is focusing initially on:

- Integration of data to develop consistent hydrogeochemical models
- Management of scientific drilling and “quick look” interpretation of data in real time
- Planning of geophysics for coastal settings

Outline of future developments (2)

Other test cases associated with advanced repository designs and “next generation” PA are initially running in parallel, but these will be coupled as soon as practically possible. Clear interfaces arise for all 3 geosynthesis sub-topics as interactions with design and PA teams will be needed to define:

- Requirements for hydrogeochemical models and priorities in case of conflicts between different data sampling approaches
- Feedback to decision-making in the event of surprises during drilling (especially if programme changes needed)
- Requirements for the site model, as input for cost-benefit analysis for the comparison of alternative methods

ISIS:
Concept and Approach

Workshop to Review the Progress of the Development of
a Knowledge Management System (KMS) and
an integrated Information Synthesis and
Interpretation System (ISIS)

11-12 November, 2008
Tokyo

Hideaki Osawa

Presentation context

ISIS

- Concept, background and approach — Osawa
- Demonstration of application — Semba

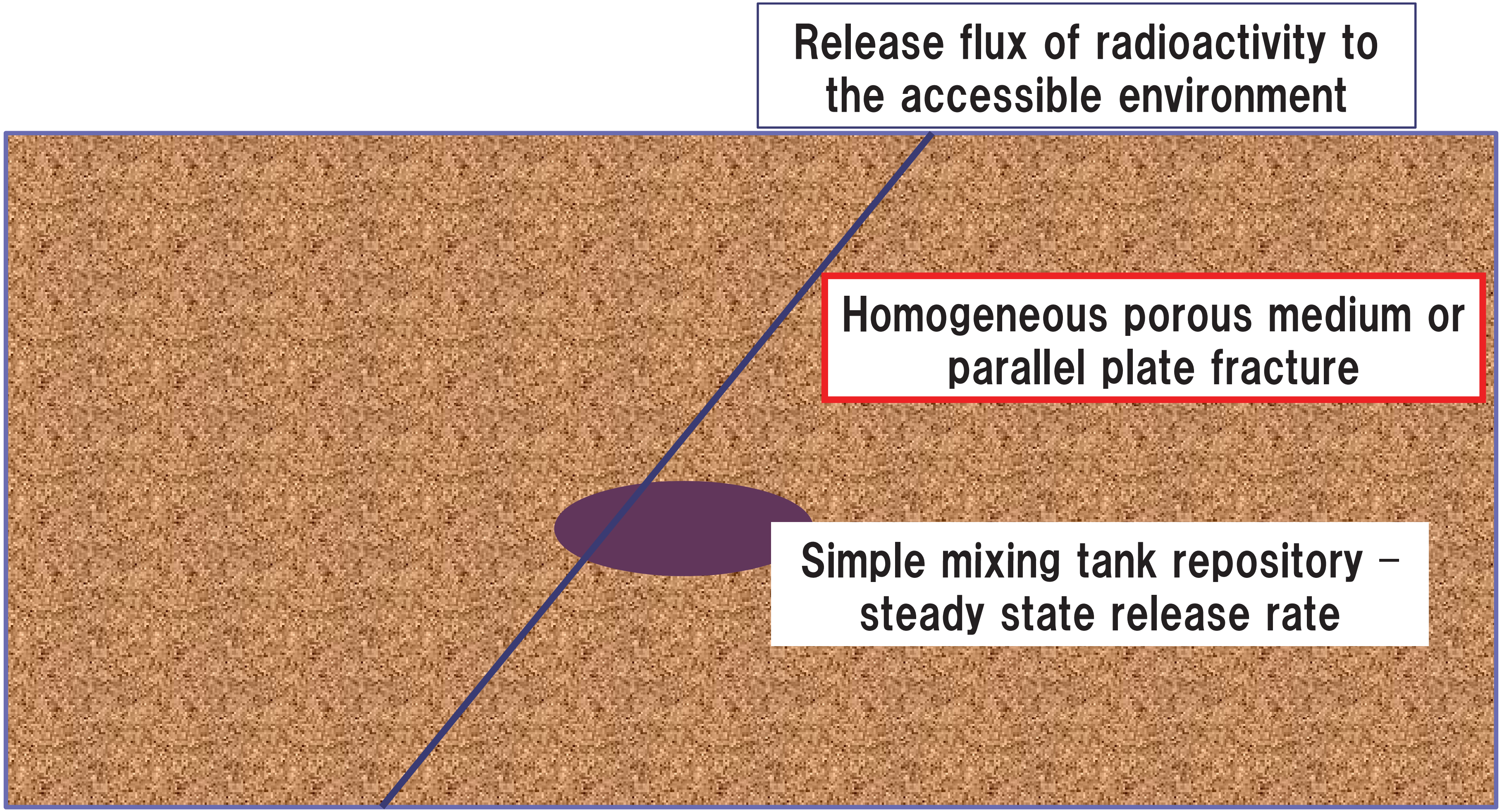
ISIS Development was carried out by JAEA under the contract with the Natural Resources and Energy Agency, Ministry of Economy, the Trade and Industry.

Presentation Outline

- Description of the geological barrier in SA – historical perspective
- Requirements of KM to support geosynthesis
- Concept of ISIS
- Approach to ISIS development with focus on knowledge acquisition and modelling

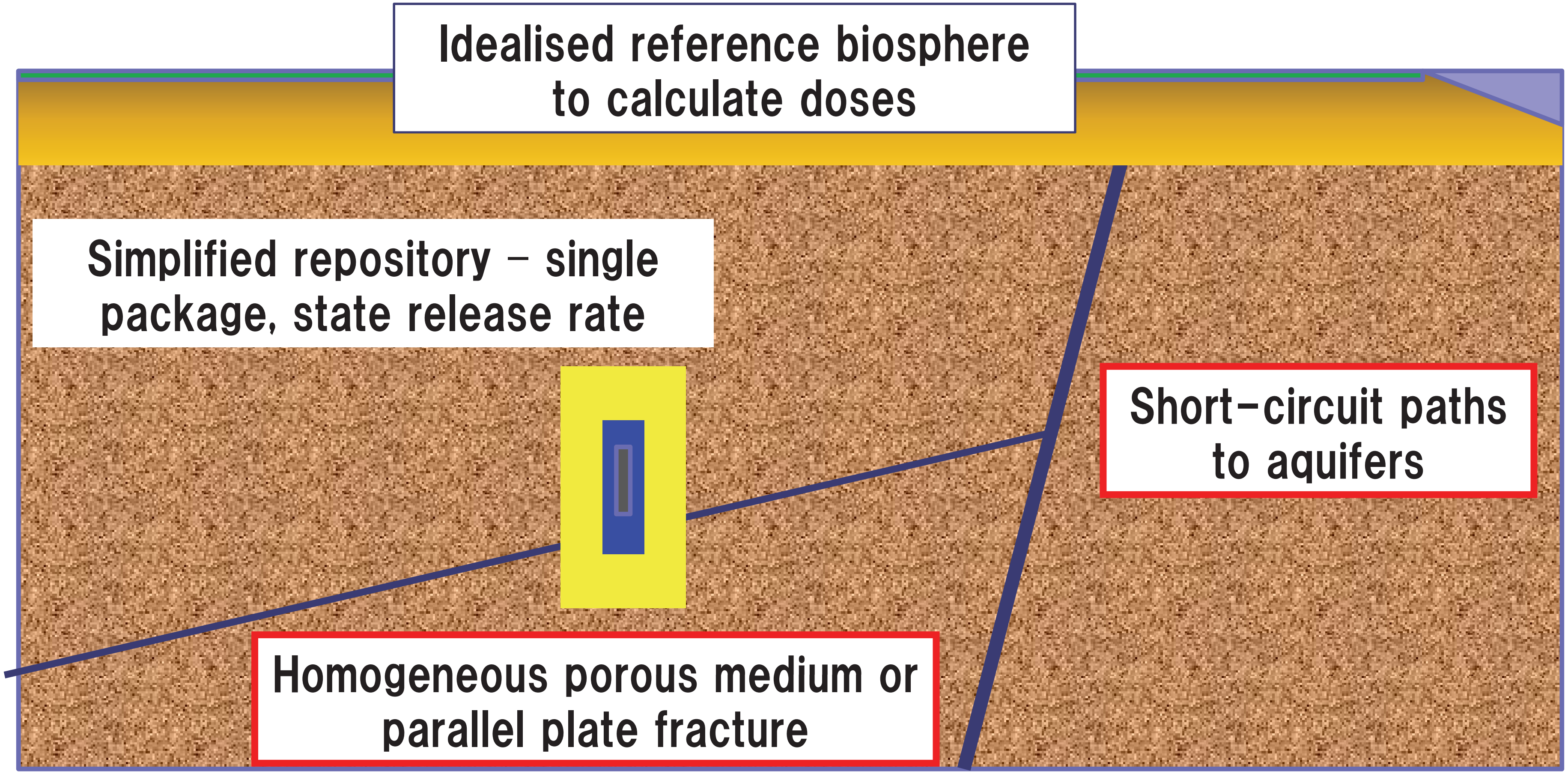
Safety assessment in the ‘70s

- Very simple representation of generic rocks
- Little consideration of structures
- Low demand for geo-information due to model limitations



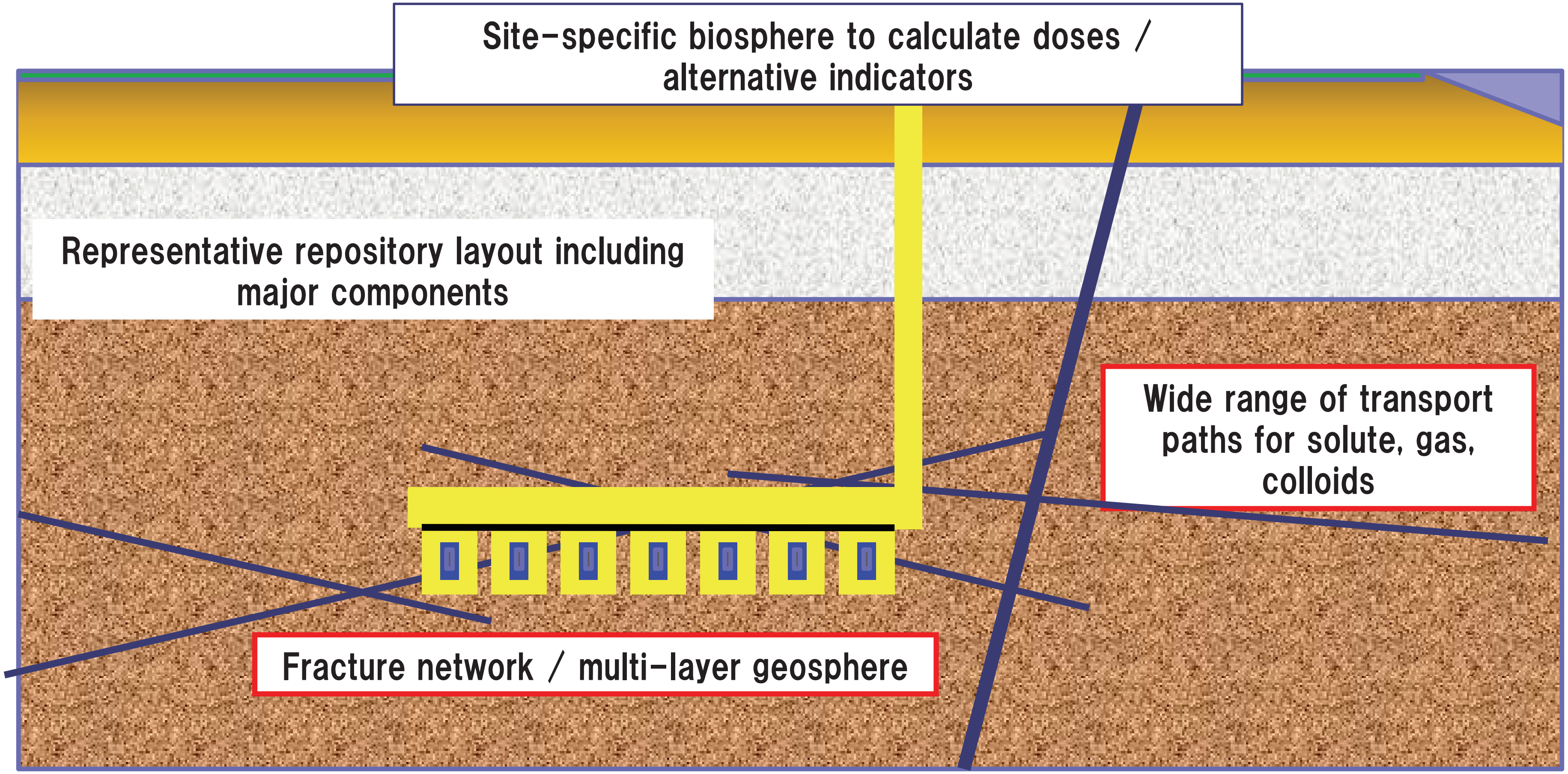
Safety assessment in the mid ‘80s

- Improved description of representative rocks
- Basic consideration of structures
- Demand for geo-information increasing



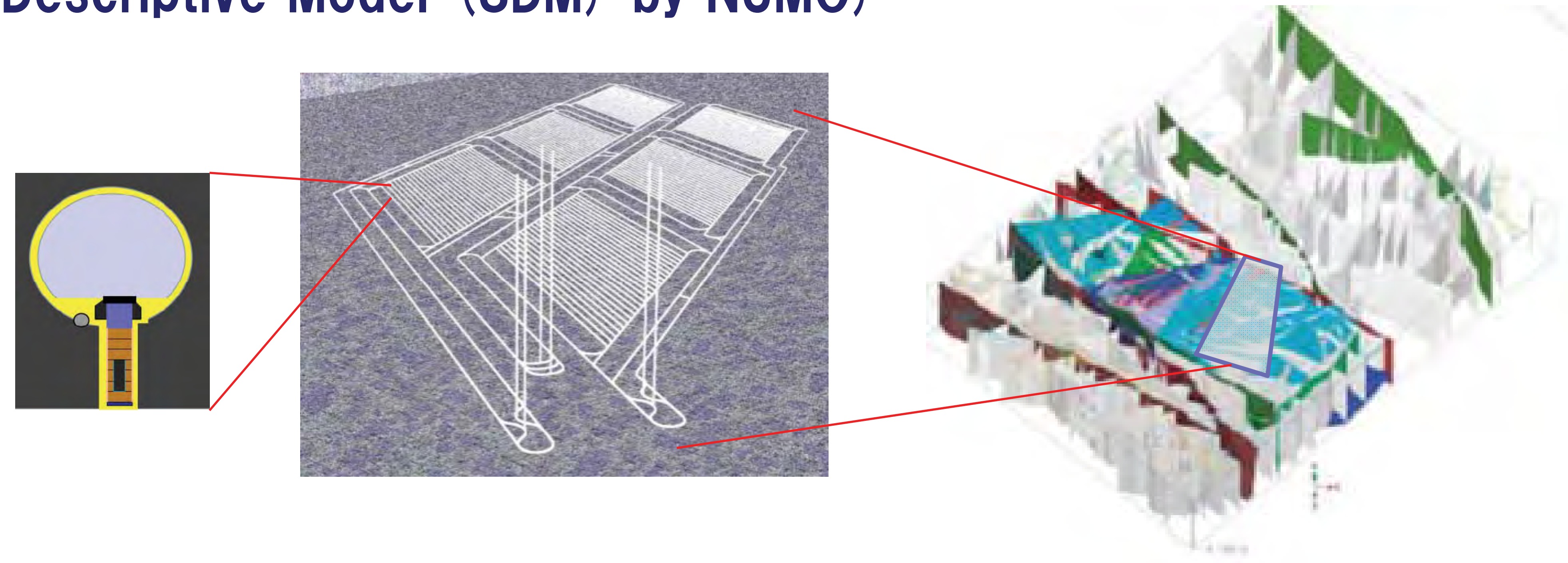
Safety assessment now

- Move towards realistic description of geological setting
- Large structures may play key role in safety case
- Huge demand for condensed site-specific geo-information



Safety Case development in the 2020s?

- Realistic representation of entire site and its evolution with time
- All structures represented in 3D: used to tailor repository design
- All "perturbations" (gas, colloids, microbes, …) explicitly represented
- Demand for Quality Assured geo-information integrated within a Geological Environmental model (GEM) (termed a Site Descriptive Model (SDM) by NUMO)



Developing a Geological Environment Model (GEM) /data set for use in a Safety Case

Preparation for future requirements / KM challenges

- Focus on needs of the user – safety functions and indicators
- Feedback requirements into the site characterisation plan
- Assuring the interface between the GEM and safety assessment / repository design teams
- Incorporating field data in a quality assured geo-scientific database: practical aspects
  - Steps in GEM development
  - Flow chart for modelling the geological environment
  - Quality Assurance

Safety functions and indicators

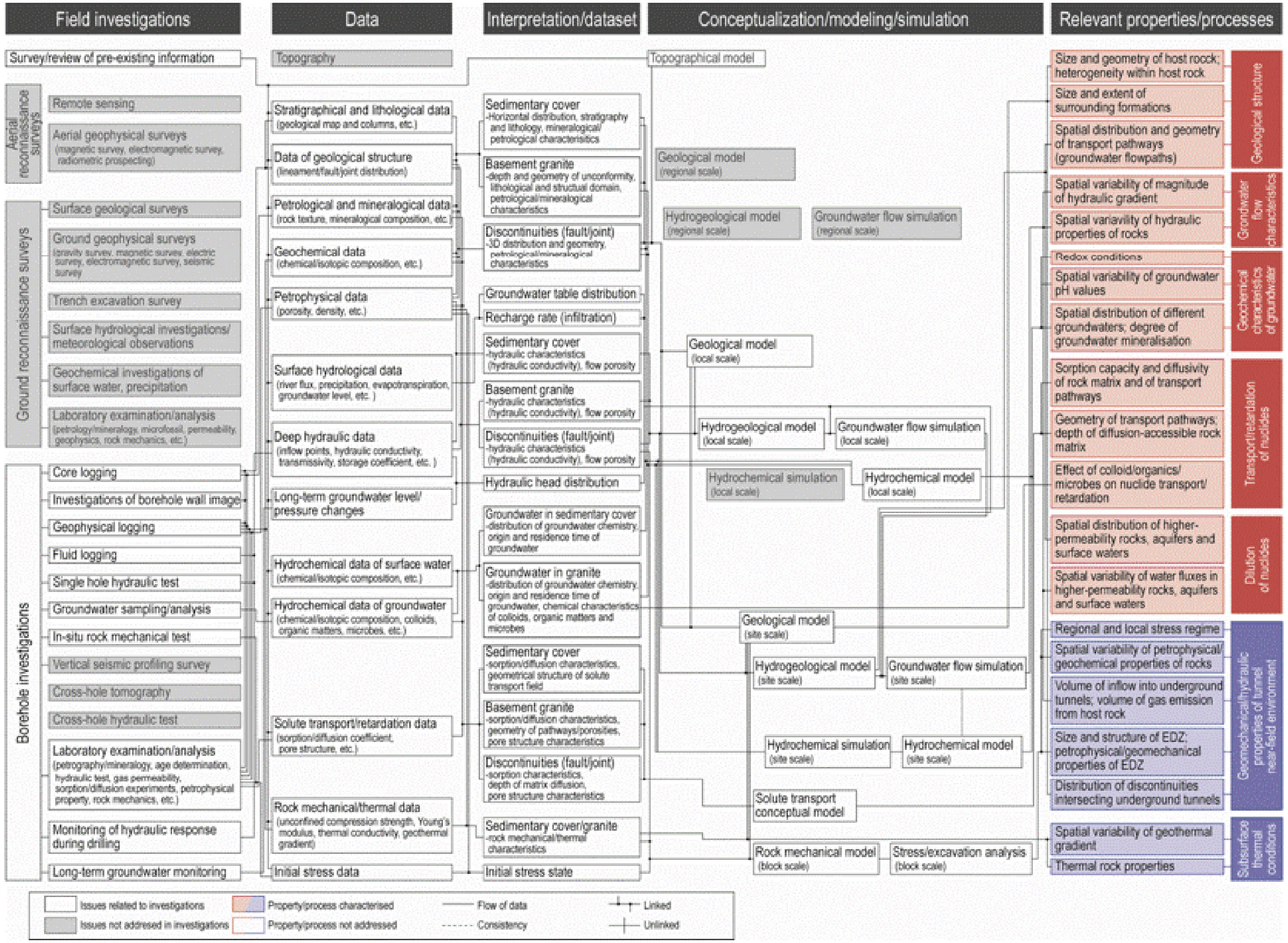
- Safety function
  - a role through which a repository component contributes to safety
  - Example: isolation by the overpack
- Safety function indicator
  - measurable or calculable property that indicates the extent to which a safety function is fulfilled
  - Example: overpack lifetime
- Safety function indicator criterion
  - a quantitative limit
  - Example: minimum overpack lifetime of 1 ka

…relatively easy to specify for EBS, trickier for geological barrier

Geosynthesis – linking data to user needs

Information flow diagrams have been used to couple measurements in the field to the key safety functions of the natural barrier or parameters used for repository design

BUT lack the flexibility to respond to surprises and have limited functionality for autonomic data processing



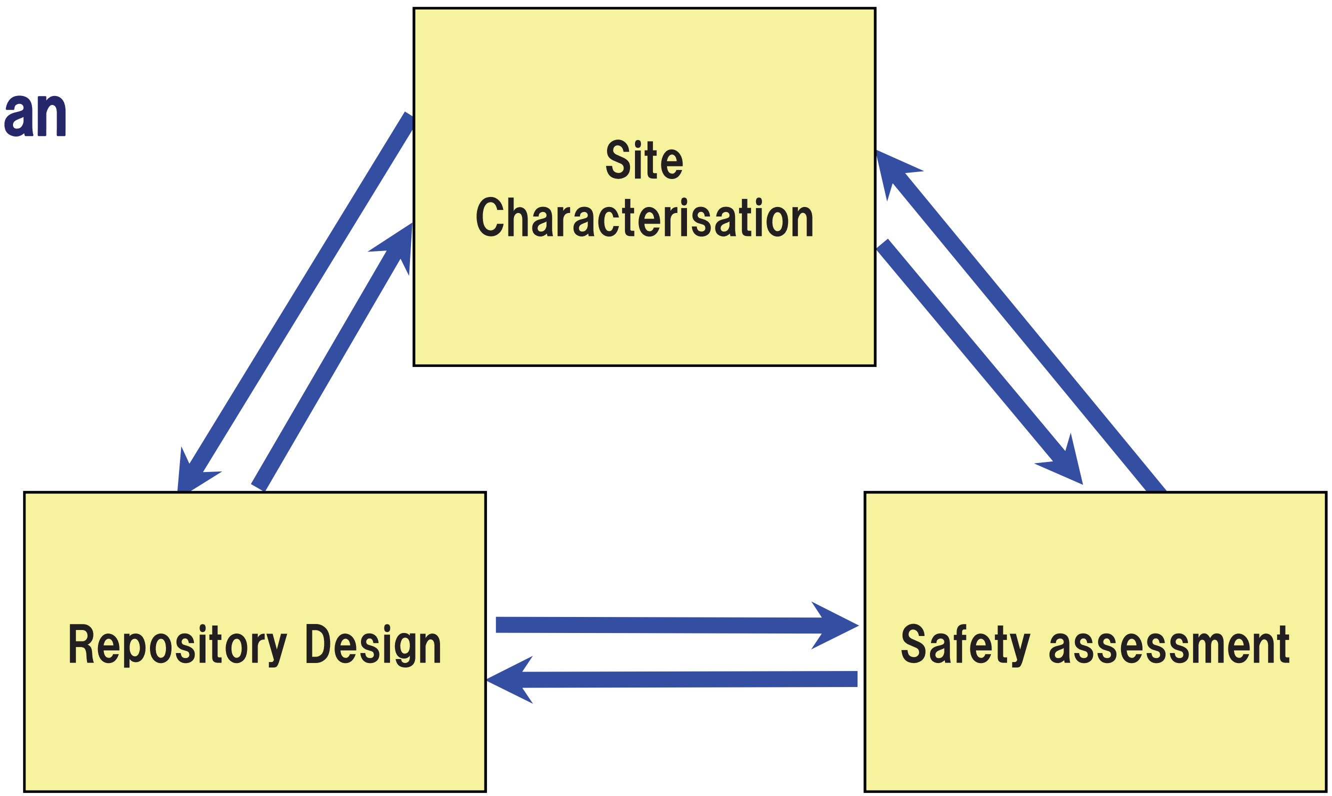
Issues for site characterisation

Assure key site properties (NB NUMO siting factors)

- Long-term stability
- Favorable geological environment to ensure EBS longevity
- Natural barrier to the release of RN
- (Dilution at the GBI)

Iterative optimisation

- Characterisation plan
- Design
- SA



From GEM to safety assessment

- Process understanding
  - GEM should provide a basis for specifying the evolutionary processes to be considered in the Safety Assessment
  - It is complemented by supporting information:
    - Basic science (e.g. thermodynamics)
    - Data from other sites
    - Natural analogues
    - …
  - Integrated within a geosynthesis, to support a safety case
- Safety Assessment Data
  - Site-specific data essential for safety quantification
  - also consider non-site specific information
  - add judgments on how to handle the uncertainties (GEM aims at describing uncertainties, safety assessment needs further quantification)
  - A report – using a structured procedure for assessing all sources of uncertainties for parameters in the safety assessment calculations and also suggests values to be used

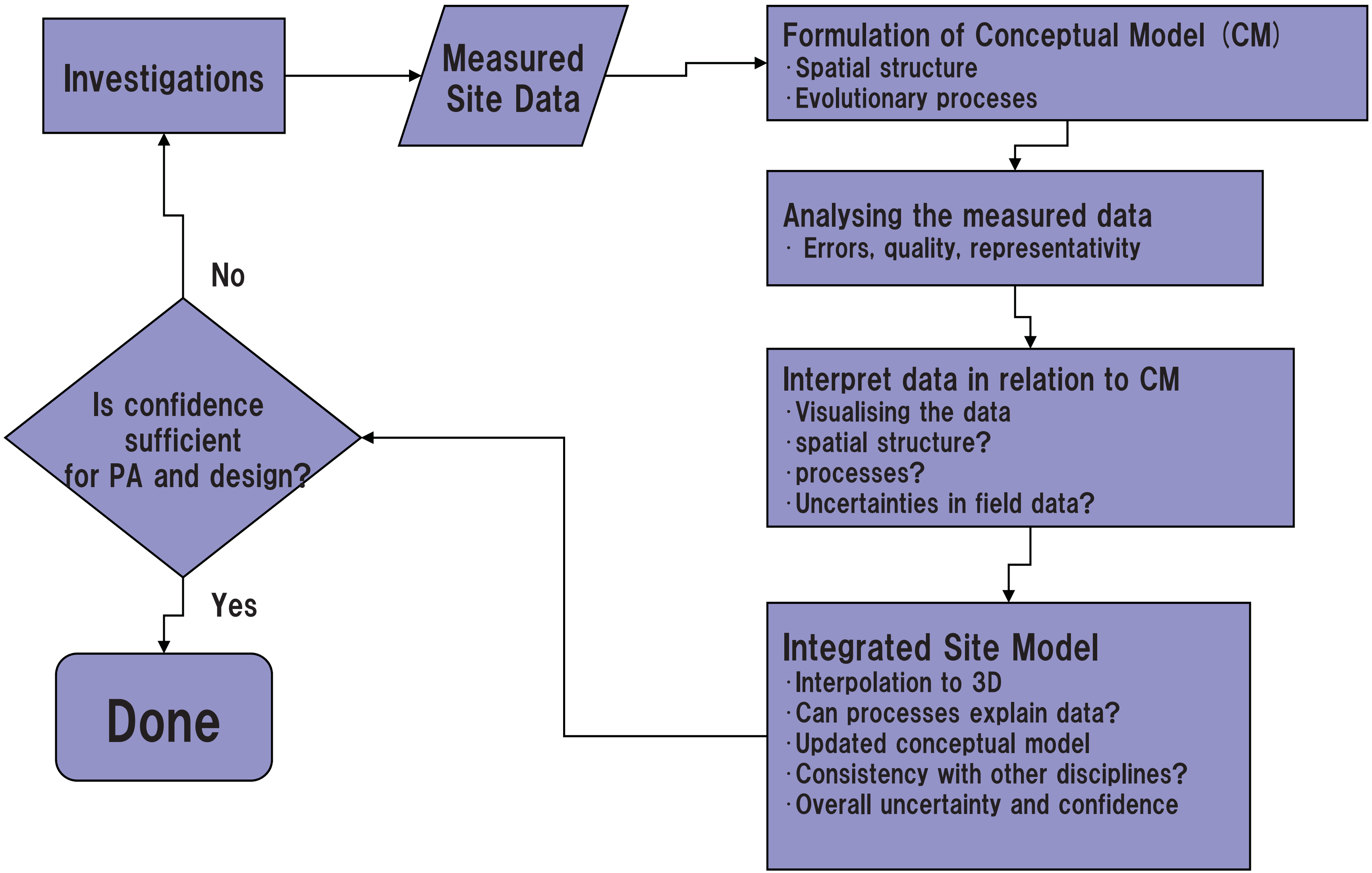
Storing data in a geo-scientific database

- Store the investigation results (primary data) in a common database.
- Should be established at an early stage, together with a plan for updating its content and structure.
- In planning and setting up the database the following should be considered:
  - should be able to handle all the measurement data produced by the planned investigation (NB information explosion emphasised by Umeki-san)
  - both measured data and interpretations should be entered into the database
  - all data should include assessment of uncertainties and should be tested for reasonableness – with feedback to data producers in the case of identified problems
  - strict QA and version control procedures are needed, to ensure that all users work on a common version, which is frozen (and archived) at key project milestones
  - user-friendly software should facilitate access and data management
  - security and archive longevity

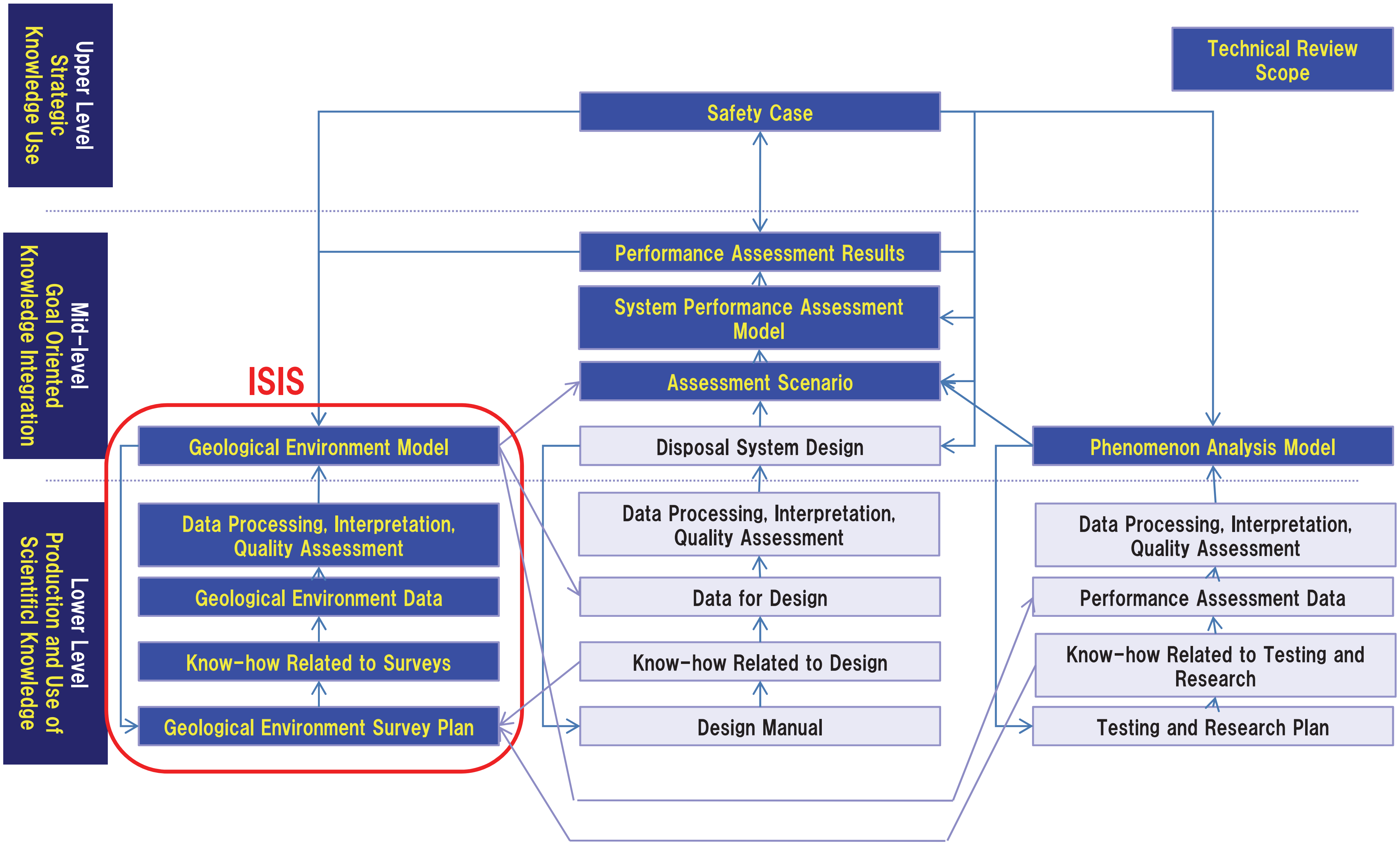
Steps in GEM development

- Presentation/formulation of conceptual model
  - Hypotheses on spatial structures and on key evolutionary processes
  - Based on past experience, previous iteration
- Analysing measured data
  - Quality, errors and representability of the data
- Interpreting data in relation to conceptual model
  - Visualising the data in 3D and/or in relation to other information
  - Assessing support of the conceptual model of spatial structures
  - Assessing evidence of evolutionary processes
  - Propagating uncertainties in data and interpretation methods
- Integrated site model
  - Interpolation/extrapolation of measured site properties to form a full three-dimensional description
  - Quantified assessment of processes – is it reasonable to explain currently measured data as a result of identified evolutionary processes?
  - Updated conceptual model
  - Assessing consistency between disciplines and sub-models
  - Determination of overall uncertainty and confidence in the model

Flow chart for GEM development



Role of ISIS in JAEA KMS



Requirement for KMS and intelligent system in integration of GEM/data-set for use in SA

- Supporting planning, implementation and integration of SDM/data-set for site characterization based on past experience and know-how obtained the URL's R&D etc.
- Aiding user-friendly communication with experts in the different disciplines
- Providing flexible restructuring of information for performance assessment and design teams

Concept of ISIS

Key attributes to development of ISIS

- Blackboard architecture
- Hybrid system
- Problem-solving method
- Expert system development tools

…general concepts were explained by Hioki-san; these are implemented in geosynthesis test cases

Approach of ISIS development with focus on knowledge acquisition and modeling

- Procedure
- Task flow analysis
- Identification of relevant knowledge element
- Definition on ontology model
- User interface for rule-base development

From knowledge acquisition to ES development

Knowledge Acquisition

I. Task flow organization

II. Extraction of related knowledge items

Knowledge Modeling

III. Construction of ontology model in Protégé

VI. Syntax analysis of rules and cases

Expert Systemization

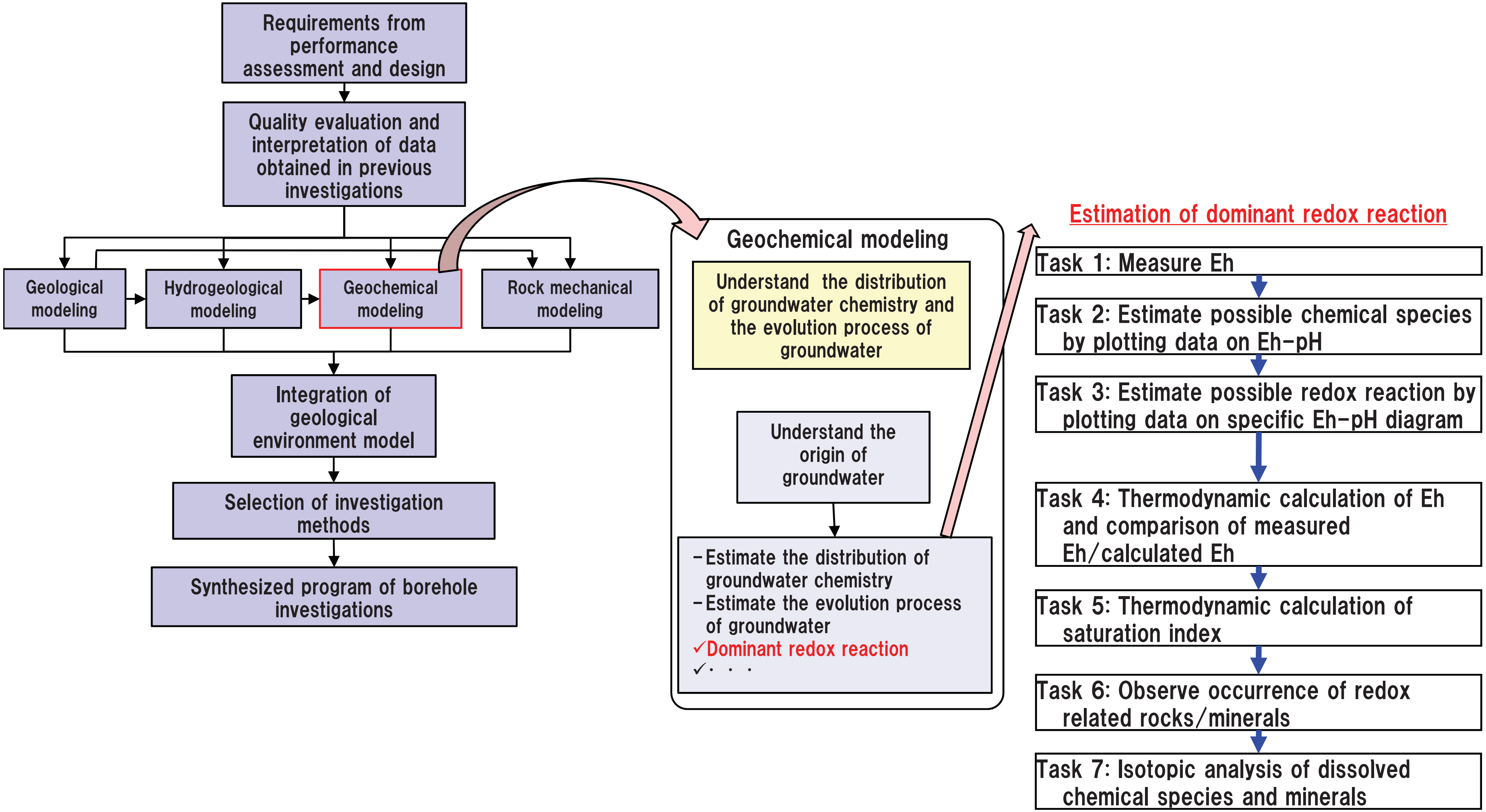
V. Creation of an interface template and formulating knowledge elements as a menu, based on the results of syntax analysis.

VI. An expert uses the interface in step "V" to create the rule base and case base by selecting knowledge elements and syntax.

VII. The expert system group is produced automatically.

Detailed System Setup

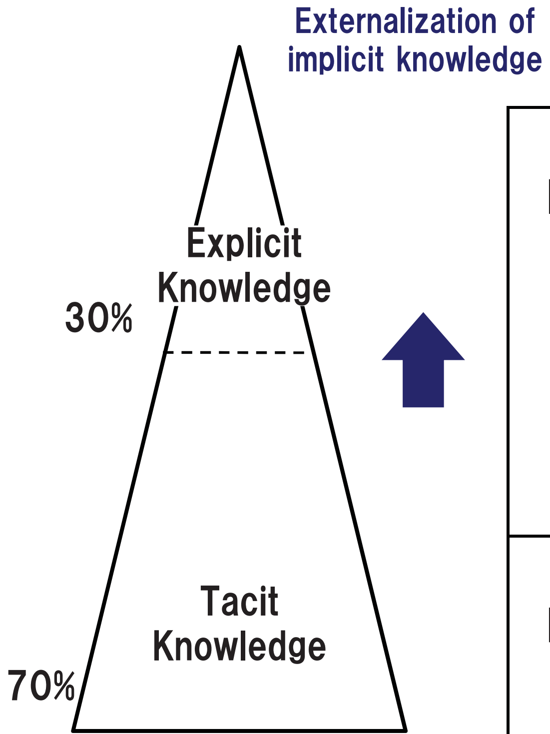
Task flow analysis



Identification of relevant knowledge elements

－ Tacit knowledge and explicit knowledge －

Tip of an iceberg !



Explicit Knowledge	•Procedure of investigation •Procedure of analysis •Applicability of method •Work flow etc.	•Process model •Mathematical model •Theory •Fundamental principle of technology •Technic of analysis •Constrained conditions of methods etc.
Tacit Knowledge	•Experience •Perceptiveness •Experienced skill etc.	•Image analysis •Classification of rock/mineral etc.

Identification of relevant knowledge element

– Task knowledge and domain knowledge –

Shallow Knowledge

Deep Knowledge

	Definition	Needed Contents
Task Knowledge (dynamic solving procedure in the task)	Knowledge that explains the problem-solving procedures in the task such as measurement, observation, analysis, modeling, evaluation, judgment, interpretation. (e.x. hydrogeological modeling)	- Aim of the task - Received knowledge from preceding task - Provided knowledge to subsequent task - Needed resources - Contents included in the output
Domain Knowledge (main static objects in an application domain)	Knowledge which is valid and directly used for a selected domain such as definition of technical word, scientific law. (e.x. lithology, fracture zone, hydraulic conductivity, deterministic model)	- General knowledge such as that written in textbooks - Knowledge defined in other tasks - Knowledge defined in the task concerned

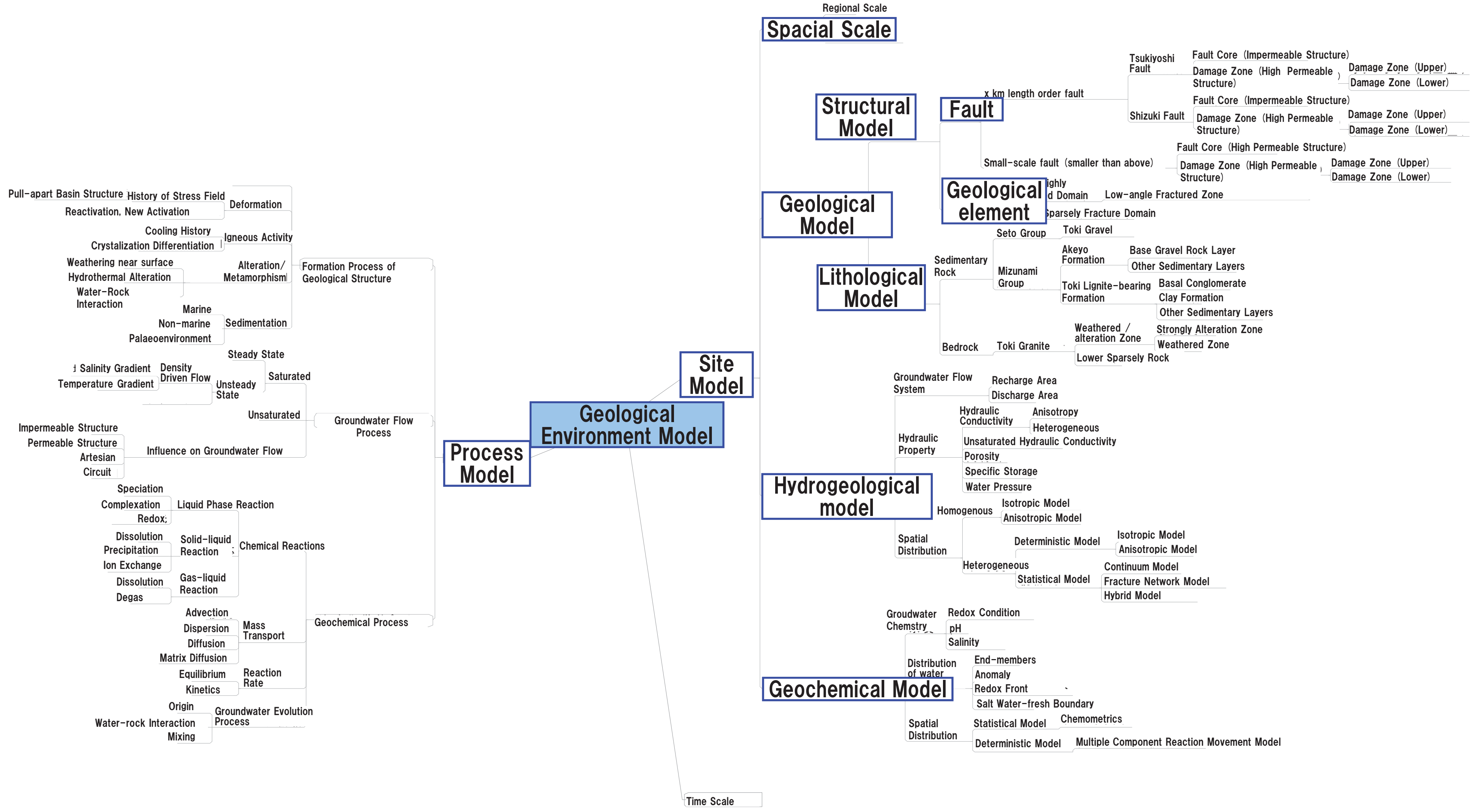
Identification of relevant knowledge element

- Rule-base and case-base -

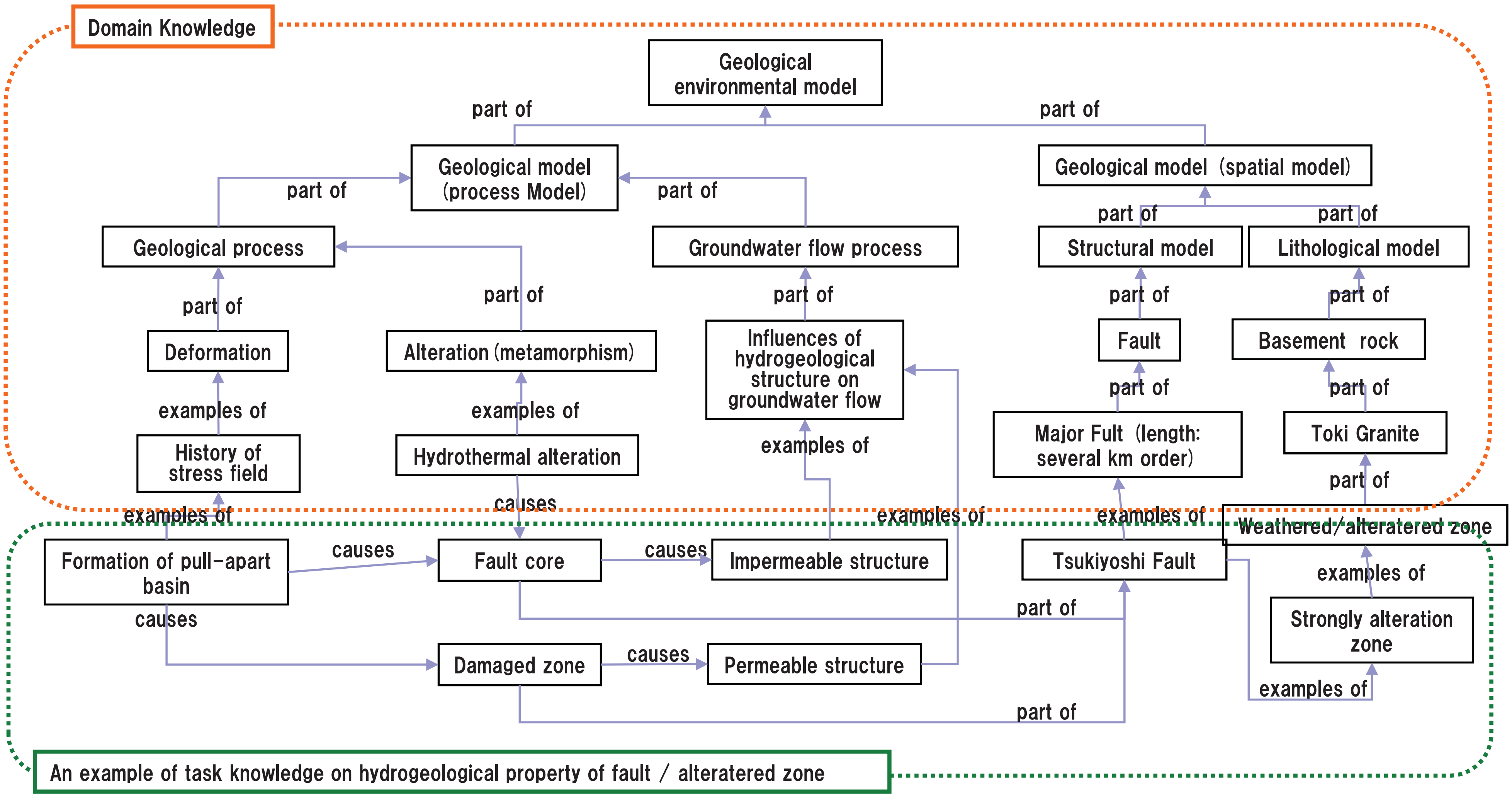
Rule-base	Decision-making rules within tasks of site investigation, represented using IF...THEN format	e.g. Selection of drilling methods If full core recovery needed YES Then a wireline drilling method should be selected NO then a non-core drilling method should be selected (tricon bit etc.)
Case-base	Cases how a problem in site investigation was solved in the past, to suggest ways to handle similar problems in the future	e.g. Troubleshooting of drilling fluid loss

Definition of ontology model
Example 1: Knowledge mapping

Geological environment in Tono

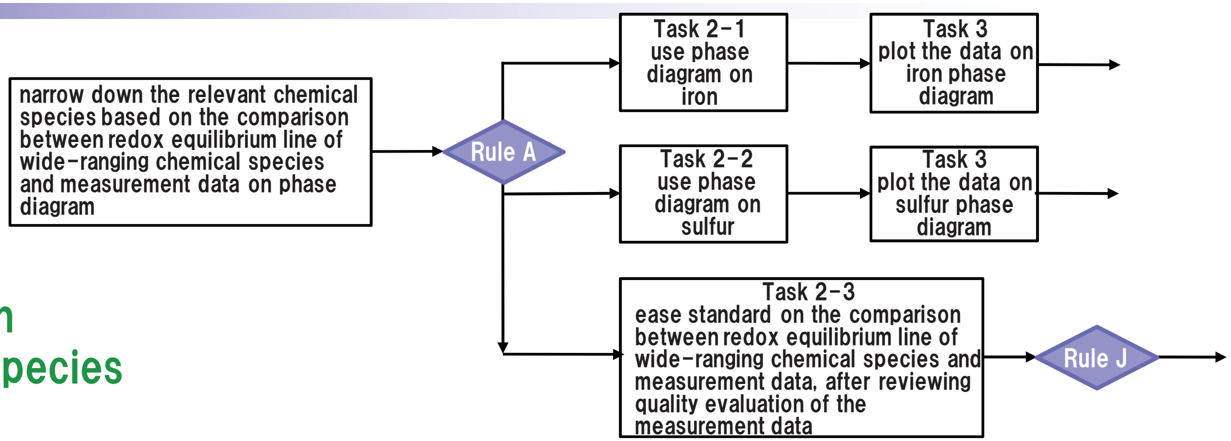


Definition on ontology model
– Example 2: Knowledge network –



Formation of geological structure relevant to pull-apart basin

Example of rules given from experts

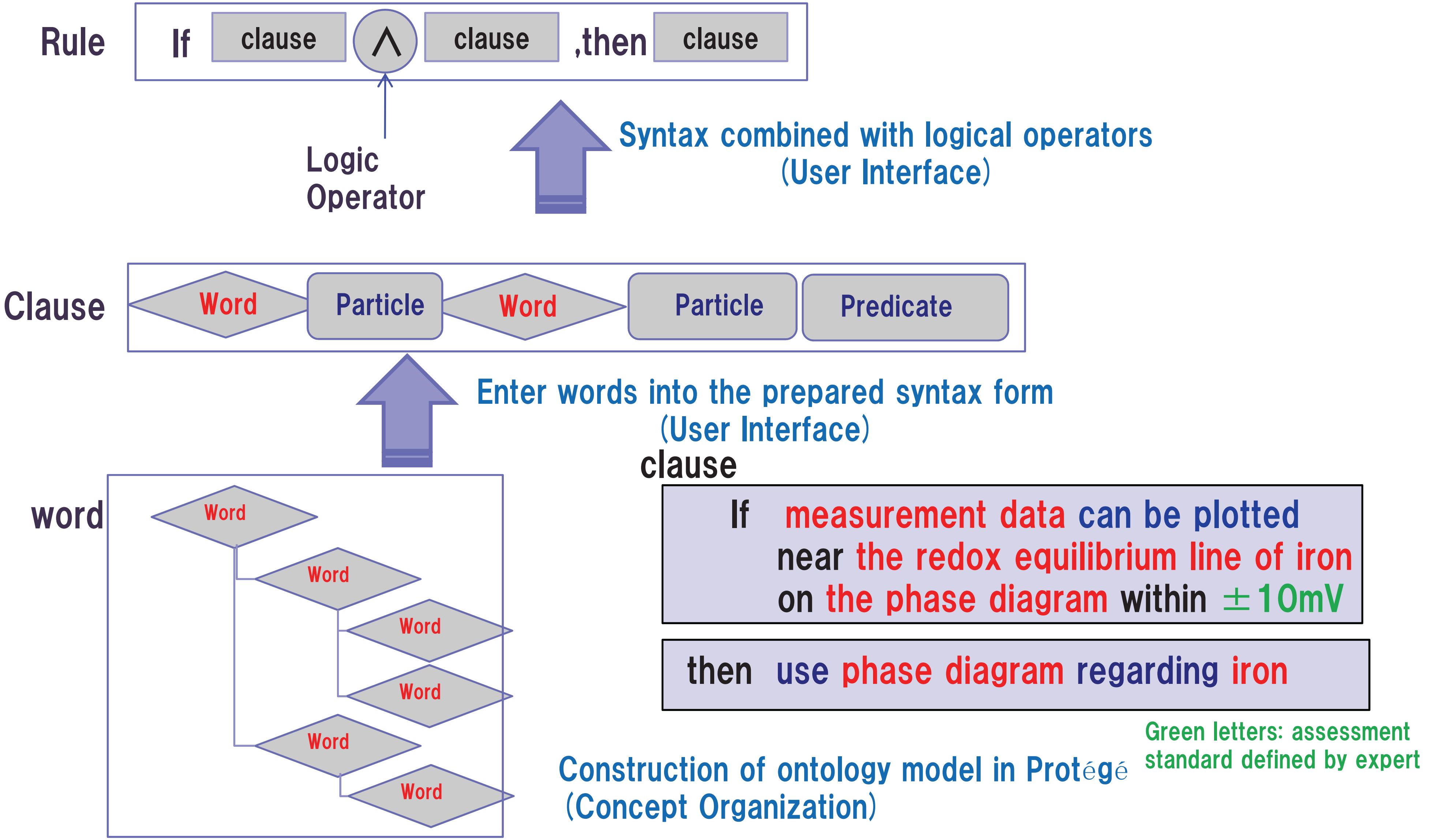


Estimation of a dominant redox reaction
Task:Estimation of possible chemical species

Rule	If	Then
Rule A1	measurement data can be plotted near the redox equilibrium line of iron on the phase diagram (within ±10mV)	use phase diagram regarding iron
Rule A2	measurement data can be plotted near the redox equilibrium line of sulfur on the phase diagram (within ±10mV)	use phase diagram regarding sulfur
Rule A3	measurement data can not be plotted near the redox equilibrium line on the phase diagram	ease criteria on the comparison between redox equilibrium line and measured data, after reviewing quality of the data
Rule ••	•••	•••
Rule J1	easing criteria can be adopted (±50mV can be adopted because variation of data measured by some different electrodes are within ±50mV)	select the phase diagram of the chemical species within easing criteria (within ±50mV) *: In the following analysis, error of ±50mV should be considered.
Rule J2	easing criteria can not be adopted	This data should not be used in the following analysis because the data may be influenced by degassing etc.

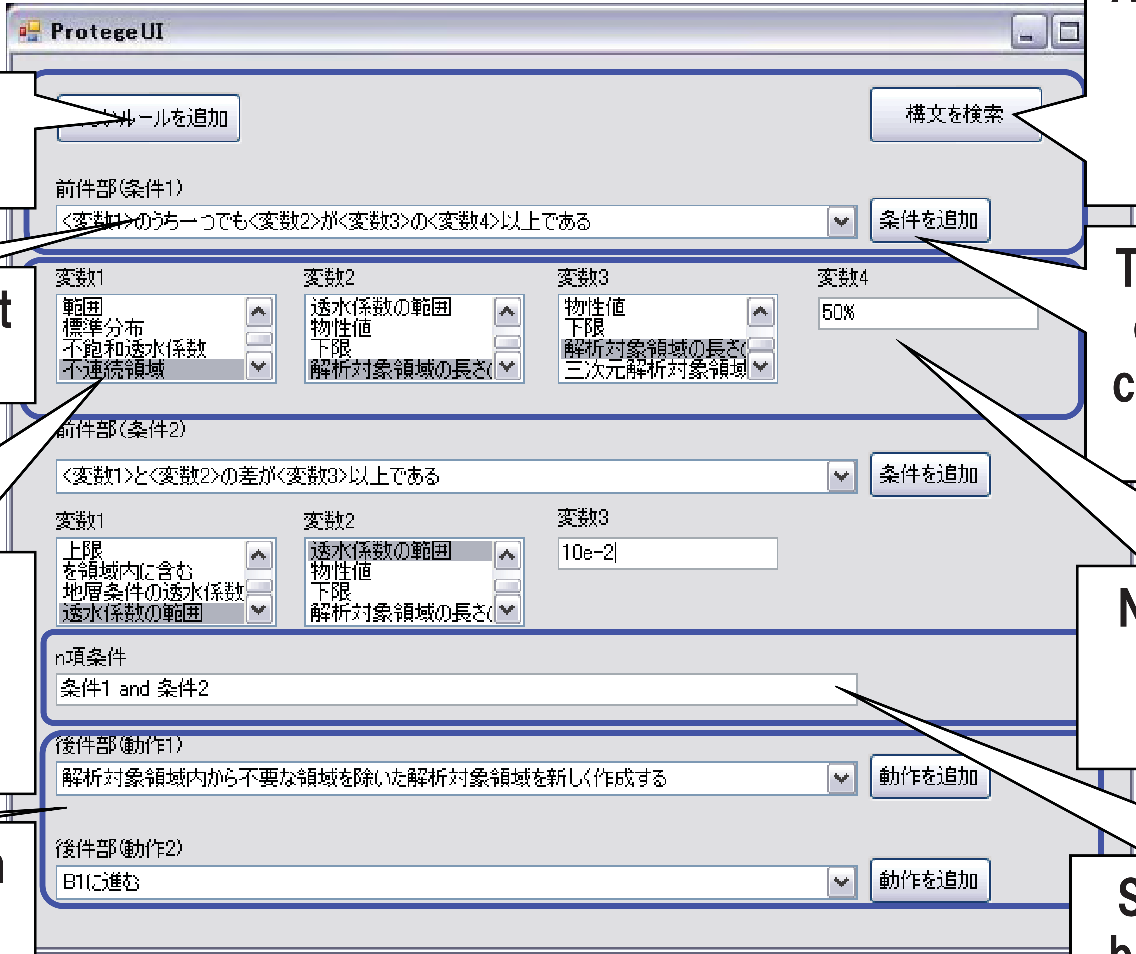
User interface for rule-base development

- Hierarchy in knowledge; word, clause and rule -



User interface for rule-base development

A Protégé module linked with JESS



Add new rule

A large number of clauses can be searched. (next page)

Select antecedent from choices

There are no limits on the number of conditions that can be added.

The parameters of the condition vary depending on their details and number

Numerical values and letters can also be added.

Multiple actions can be added through selections for the consequence

Select relationship between conditions (and | or | not)

ISIS:
Design and Development

Workshop to Review the Progress of the Development of
a Knowledge Management System (KMS) and
an integrated Information Synthesis and
Interpretation System (ISIS)

11-12 November, 2008
Tokyo

Takeshi Semba

Presentation context

ISIS

- Concept, background and approach Osawa
- **Demonstration of application Semba**

ISIS Development was carried out by JAEA under the contract with the Natural Resources and Energy Agency, Ministry of Economy, the Trade and Industry.

Presentation Outline

- Background to the tools and test cases
- Demonstration of the software

KMS tools for ISIS development

- Problem 1: How can the production and use of diverse, multidisciplinary knowledge within geosynthesis be effectively managed?
  - Solution ⇒ Blackboard Architecture with concepts developed by experienced generalists
- Problem 2: How can intelligence be introduced, to handle the large data fluxes involved?
  - Solution ⇒ Hybrid Knowledge and Information Systems, using qualified specialists
- Problem 3: How can required expert systems be developed efficiently and have their quality controlled?
  - Solution ⇒ Expert System Development Tools, tailored for this application
- Problem 4: How can the complex information flows be efficiently and systematically acquired and organized?
  - Solution ⇒ Knowledge Acquisition Methodology (Problem Solving Methods)
- Problem 5: How can the limitations of traditional geosynthesis methods (e.g. back-fitted, one-of information flow diagrams) be avoided?
  - Solution ⇒ HyM Approach

Scope of Phase 1 (~FY2008)

- We carried out exercises to confirm the validity of the general approach within a limited timeframe, examining applicability for:
  - The diversity of target fields of expertise
  - The diversity of surveyed geological environments
  - A variety of related tasks, ranging from site characterisation planning to model construction
- By creating a prototype using commercially available software, we assessed the applicability and limits of a generic system and examined the necessity of developing a new system.
- For new software, such as expert systems, we clarified the areas that needed to be improved and assessed their applicability through case study trials.

Key functions of ISIS group-ware (1/3)

- Electronic Message Board Function
  - Location for experts to debate topics with a degree of continuity
  - Each debate on a specific topic is displayed as a tree or thread.
  - As an optional function, we would like to have an automatic debate summarization function.
- Knowledge Portal Function for Knowledge Sharing and Integration
  - Online system for creating and updating knowledge through decentralized cooperation.
    - Discussion diagram construction support system
    - Ontology editor
    - Wiki
    - Visual concept model tools

Key functions of ISIS group-ware (2/3)

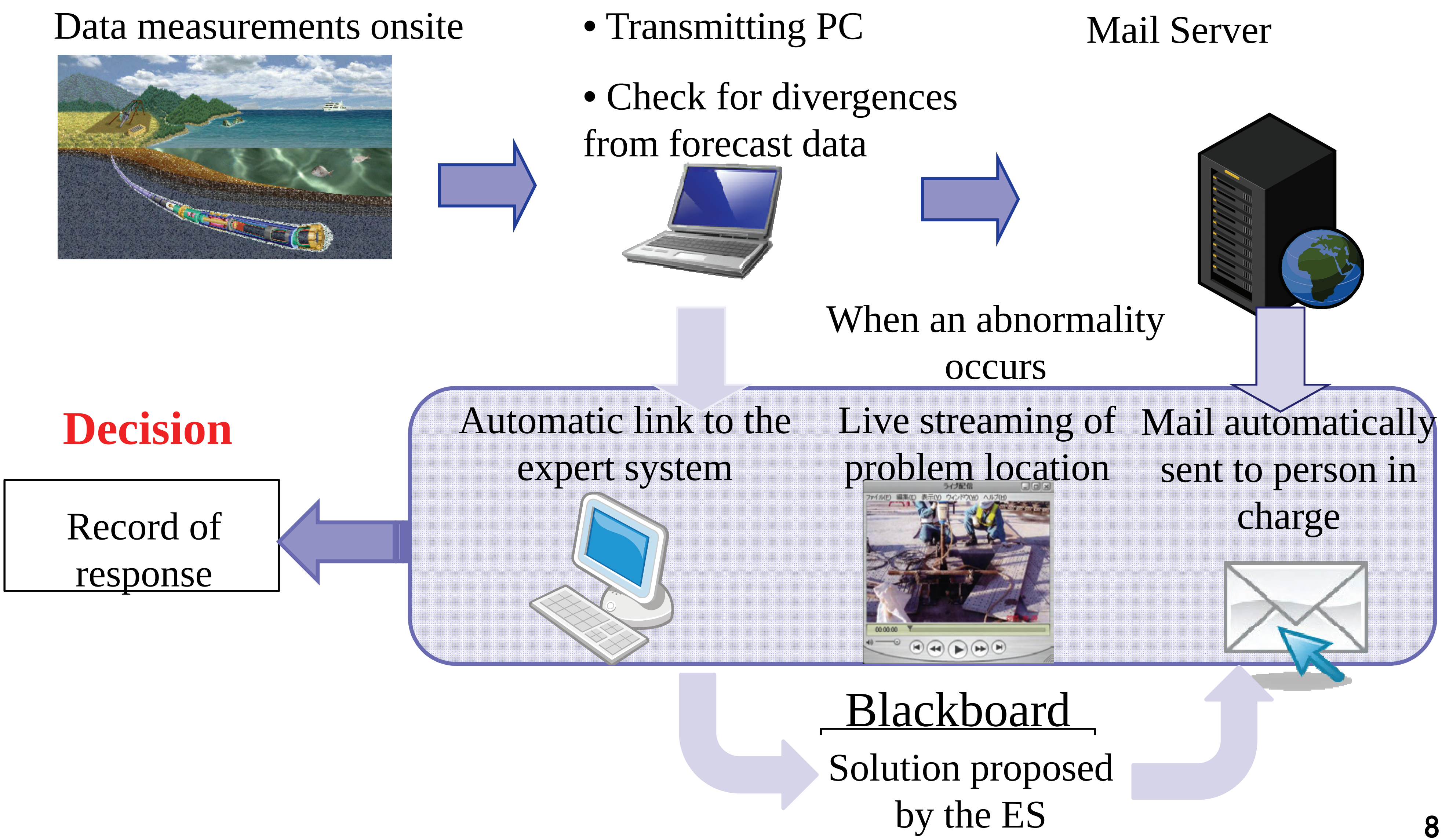
- Video Chat Function
  - Expert knowledge difficult to express with language is sometimes expressed with expression, body language, work details and the object being considered (visible knowledge). We consider video chat to be an effective way to transmit this kind of knowledge.
- PC Sharing Function
  - This function should allow members to simultaneously view work being carried out (e.g. model development or calculational procedures) on one PC through the internet. Furthermore, they should be able share the ability to operate the PC while communicating with videophones or other devices. Cooperation may also be facilitated by recording and archiving the operating procedures of particular experts.

Key functions of ISIS group-ware (3/3)

- Live Streaming Function
  - Cooperation can be facilitated by communication of live images streamed from experiments and field work at laboratories and underground research facilities, which can be distributed to all relevant members.
- Assessment Support Function
  - In projects such as geosynthesis, research results and plans in individuals fields need to be assessed based on the reviews of experts in other related fields.
  - We also see this kind of assessment as a part of cooperative work, and we will make the following tools accessible in this system.
    - ESL Assessment Tools
    - AHP Assessment Tools

Example of real-time support by ISIS / group-ware

Alarm System Function When an Abnormality is Discovered during drilling



The JAEA KMS & ISIS:
Structured discussion session

KMS/ISIS workshop
11-12 November, 2008
Tokyo

Hiroyuki Umeki

Format & programme

Discussions focused by questions (Knowledge Acquisition)

- Block 1 – the KMS in general
- Block 2 – ISIS and the application of KM to geosynthesis

Break: scribes integrate input

Review of comments & suggestions (Knowledge Synthesis & QA)

- Structured by question (integration of blocks 1 & 2)

Block 1

The JAEA KMS

The Questions

a) Are the project goals clear and adequately justified and the effort invested appropriate to requirements?

b) Are the approaches adopted reasonable, the level of work representative of the state of the art and the chances of reaching a successful output sufficiently high?

c) Have the results to date been clearly presented and are interpretations, conclusions and proposals for future work reasonable?

d) Are there ways in which the project could be improved?

e) Are there any areas where collaboration with other organizations would be beneficial?

f) Any other comments?

KMS goals

Are the project goals

- Clear?
- adequately justified?

Is the effort invested appropriate to requirements?

KMS approaches

Are the approaches adopted reasonable?

Is the level of work representative of the state of the art?

Do the chances of reaching a successful output seem sufficiently high?

Output

Have the results to date been clearly presented?

Are interpretations and conclusions well supported

Do proposals for future work seem reasonable?

Improvements

Are there ways in which the project could be improved?

- Organisation?
- Programme of work?
- Priorities?
- Technology used?
- ...

Collaboration

Are there any areas where collaboration with other organisations would be beneficial?

- Organisations in Japan?
- Organisation in other countries?
- International or multinational organisations?

Any other comments?

...on any aspect of KM

Block 2

ISIS and use of KM in geosynthesis

The Questions (again)

a) Are the project goals clear and adequately justified and the effort invested appropriate to requirements?

b) Are the approaches adopted reasonable, the level of work representative of the state of the art and the chances of reaching a successful output sufficiently high?

c) Have the results to date been clearly presented and are interpretations, conclusions and proposals for future work reasonable?

d) Are there ways in which the project could be improved?

e) Are there any areas where collaboration with other organizations would be beneficial?

f) Any other comments?

ISIS goals

Are the project goals

- Clear?
- adequately justified?

Is the effort invested appropriate to requirements?

KMS approaches within ISIS

Are the approaches adopted reasonable?

Is the level of work representative of the state of the art?

Do the chances of reaching a successful output seem sufficiently high?

Output

Have the results to date been clearly presented?

Are interpretations and conclusions well supported

Do proposals for future work seem reasonable?

Improvements

Are there ways in which the project (ISIS or other KM methods) could be improved?

- Organisation?
- Programme of work?
- Priorities?
- Technology used?
- ...

Collaboration

Are there any areas where collaboration with other organisations would be beneficial?

- Organisations in Japan?
- Organisation in other countries?
- International or multinational organisations?

Any other comments?

...on any aspect of ISIS or geosynthesis in general

Block 3

Review of synthesis output

Goals & procedures

Check of completeness & correctness of input acquired by the scribes

Opportunity to add input or 2nd thoughts on any point

Goals of KMS / ISIS

Input from scribes...

KMS / ISIS approaches

Input from scribes...

Output

Input from scribes...

Improvements

Input from scribes...

Collaboration

Input from scribes...

Any other comments?

Input from scribes...

Thanks!

...this is the end of the programme, so thanks to:

- The JAEA team
- Supporting contractors
- Management who are backing this initiative
- ...and especially all participants for the contribution of their time and their valuable tacit knowledge

Comments on Workshop to Review the Progress of Development of KMS and ISIS

12 November 2008

Tad Miwa
Nuclear Waste Management Organization of Japan (NUMO)

Personal Comments

KMS is a practical system.
However, NUMO must consider potential difficulty in application:

- Who uses this system?

  → Technical specialists who have little geological background (e.g.)
- When should NUMO start using this system?

  → At the beginning of PI or DI?
- How should NUMO apply the system effectively?

  → During PI or DI ?
- Could the system support the top decision?

  → Must be consistent during the whole site selection process.

Personal Requests for KMS

KMS must have:

1. Easy application and uncomplicated maintenance
2. Simple customisation
3. Unsuccessful stories must be included
4. Should be easy to train new staff

→ Big potential concerns:

New staff may misunderstand that the KMS does not require any adjustment (customisation) due to lack of their technical knowledge ?

So, can NUMO rely on the KMS?

$\Rightarrow$ YES!

Thank you very much for your attention!

Vielen Danke!!

2008-10-30

Workshop to review the Progress of the Development of a
Knowledge Management System (KMS) and
its Application toward Advanced Performance Assessment (PA)

13 to 14 November 2008

Organizer:
Japan Atomic Energy Agency (JAEA)

Venue:
Tokyo Hibiya Centre
The Imperial Hotel Tower 15th Fl.
1-1-1 Uchisaiwaicho, Chiyoda-ku, 100-0011 Tokyo, Japan

Provisional Program

10 am to 5 pm, Thursday, 13 November 2008

1. Opening Remarks by Mr. Masahide Osawa, Director General, Geological Isolation Research and Development Directorate, JAEA

2. Presentations on the JAEA Knowledge Management System (KMS)
    - Concept and Approach Hiroyuki Umeki
      Design and Development Kazumasa Hioki
    - Discussion

3. Presentations on Application of KMS Technology toward Advanced PA
    - Concept and Approach Kaname Miyahara
    - Design and Development Hitoshi Makino
    - Discussion

10 am to 4 pm, Friday, 14 November 2008

4. Discussion of the projects
5. Summary of comments made based on the questionnaire

JAEA KMS/PA Workshop

- Objectives
  - Present the current progress of JAEA activities on KMS and advanced PA
  - Solicit review comments from the participants
  - Discuss how such comments could be reflected in future work, possibly including collaboration in areas of common interest
- Participants
  - All invited (international and Japanese experts)
- Information to be presented
  - Status of ongoing projects
  - Most of the detailed project output is being presented for the first time in English
- Outcome
  - A meeting record will be openly available (JAEA website?), which will include a compilation of the material presented

Questionnaire

- Are the project goals clear and adequately justified and the effort invested appropriate to requirements?
- Are the approaches adopted reasonable, the level of work representative of the state of the art and the chances of reaching a successful output sufficiently high?
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- Any other comments?

JAEA KMS/PA Workshop

Programme

Day #1 (Moderators: H. Umeki / I. McKinley; Rapporteur: L. McKinley)

10:00 - 10:05	Welcome (M. Osawa)
10:05 - 10:20	Introduction to workshop and participants
10:20 - 11:20	JAEA KMS: Concept and Approach (incl. questions) (H. Umeki)
11:20 - 11:50	Break
11:50 - 12:50	JAEA KMS: Design and Development (incl. questions) (K. Hioki)
12:50 - 14:00	Lunch
14:00 - 15:00	Advanced PA: Concept and Approach (incl. questions) (K. Miyahara)
15:00 - 15:30	Break
15:30 - 17:00	Advanced PA: Design and Development with Demonstration of the system elements (incl. questions) (H. Makino)
17:00	End

JAEA KMS/PA Workshop

Programme

Day #2 (Moderators: H. Umeki / I. McKinley; Rapporteur: L. McKinley)

10:00 - 10:05	Introduction to Discussion Session
10:05 - 11:05	Block 1 - the JAEA KMS
11:05 - 11:20	Break
11:20 - 12:20	Block 2 - Application of KM to advanced PA
12:20 - 14:00	Lunch
14:00 - 16:00	Block 3 - Review of comments & suggestions (incl. Break)
16:00	End

JAEA KMS/PA Workshop

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  - Solicit review comments from the participants
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JAEA KMS/PA Workshop

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The JAEA KMS:
Concept, Approach and Application to Developing Advanced PA Technology

Workshop to Review the Progress of the Development of
a Knowledge Management System (KMS) and
Its Application toward Advanced
Performance Assessment (PA)

13-14 November, 2008
Tokyo

Hiroyuki Umeki

Presentation context

The JAEA KMS

- **Why and what?** **Umeki**
- How and when? Hioki

} PA as an example of a key application

Note that, although there are certainly overlaps, the content of this presentation differs from that given on Tuesday

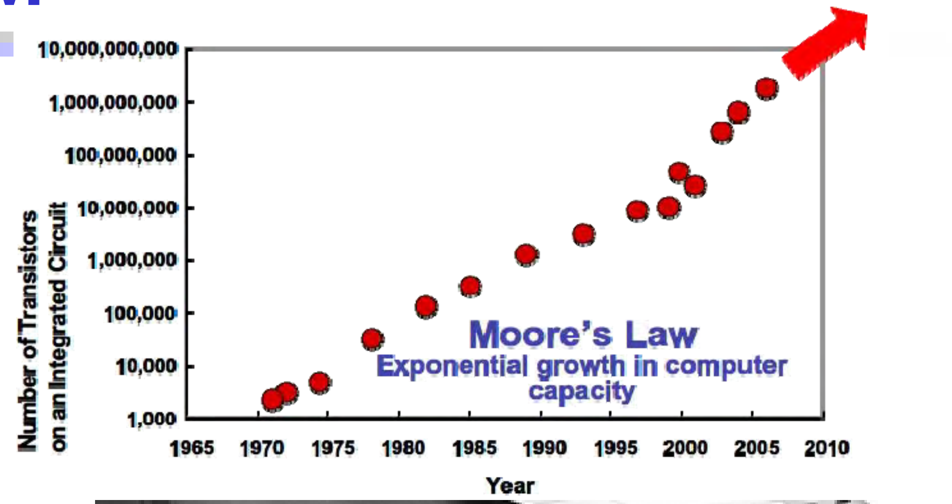
Principle from Knowledge Engineering / Safety Case development – key conclusions should be supported by multiple lines of argument

Presentation outline

- Overview of the need for KM from a PA perspective
- Specific background in Japan
- Initial concepts and constraints
- Application of advanced concepts from Information Technology and Knowledge Engineering
- Critical applications - PA
- Special near-term goals – H22 and “Coolrep”
- Summary of big messages

The need for advanced KM

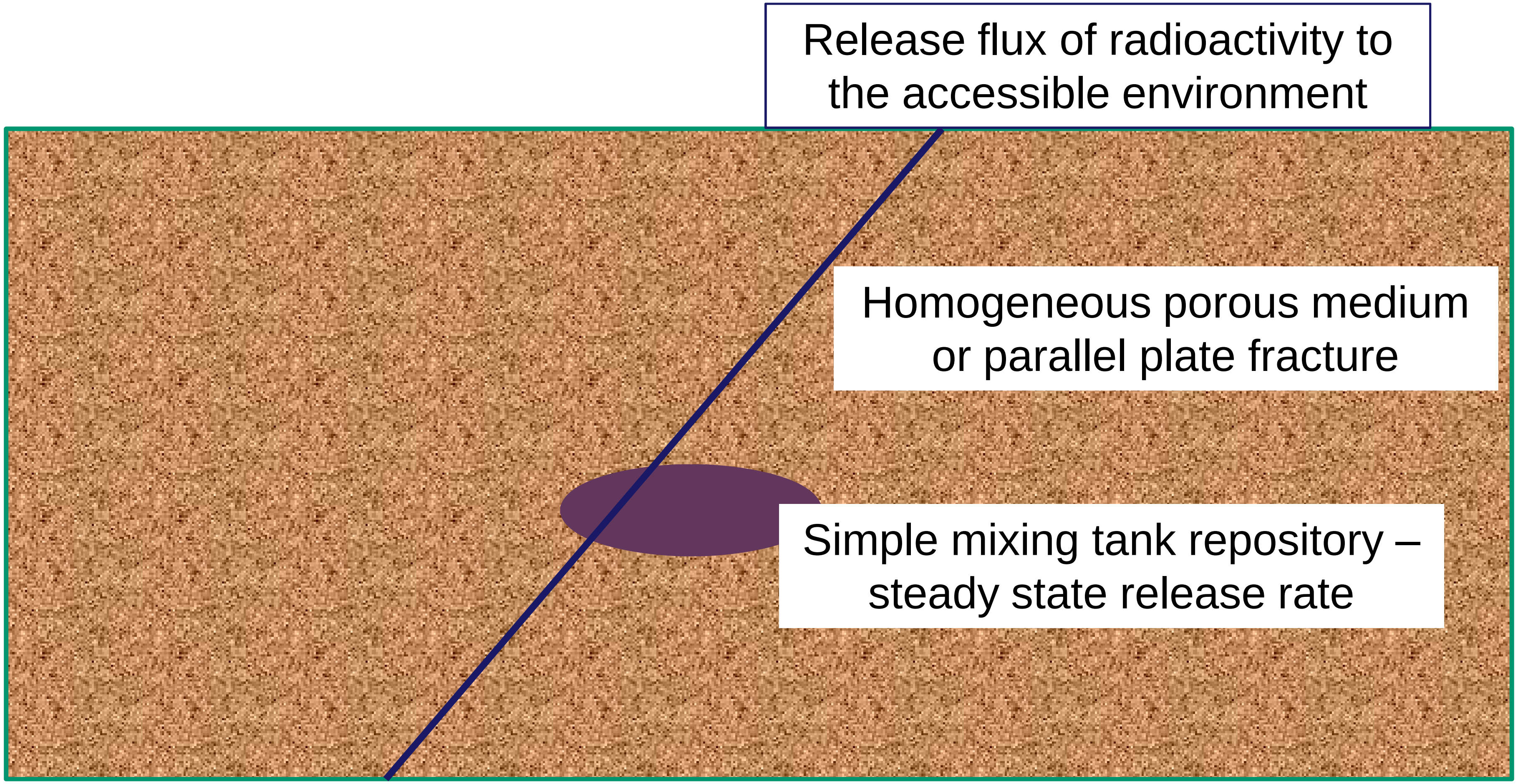
- In the early days of radwaste management, individuals could have a good overview of the entire international field
- By the ’80s and ’90s knowledge began to expand rapidly in line with the power of computers and few staff could overview even a single project
- At the start of the 21st century, KM is recognised as a critical area – particularly due to increased requirements for openness and transparency



The IBM 1401 in the early 1960's - the first mass-produced digital, all-transistorized, business computer. The basic 1401 came with 4,096 characters of memory; a Storage Expansion Unit expanded this 16K!! Cost was $125,000 – 180,000 with a weight of 1 – 3.5 tons

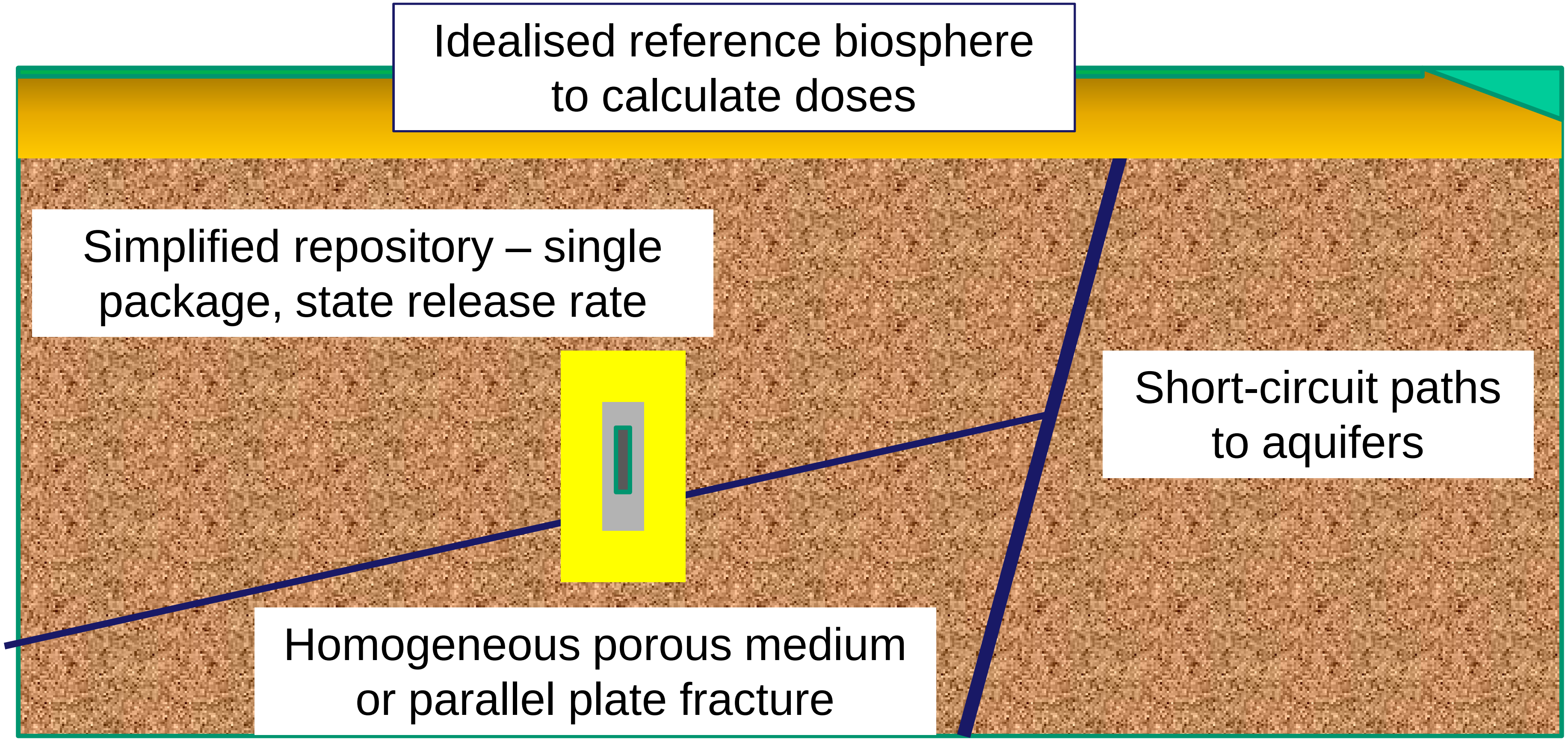
Safety assessment in the '70s

- 1D, steady state solved analytically
- Few alternative scenarios discussed qualitatively
- Output: steady-state pCi/a



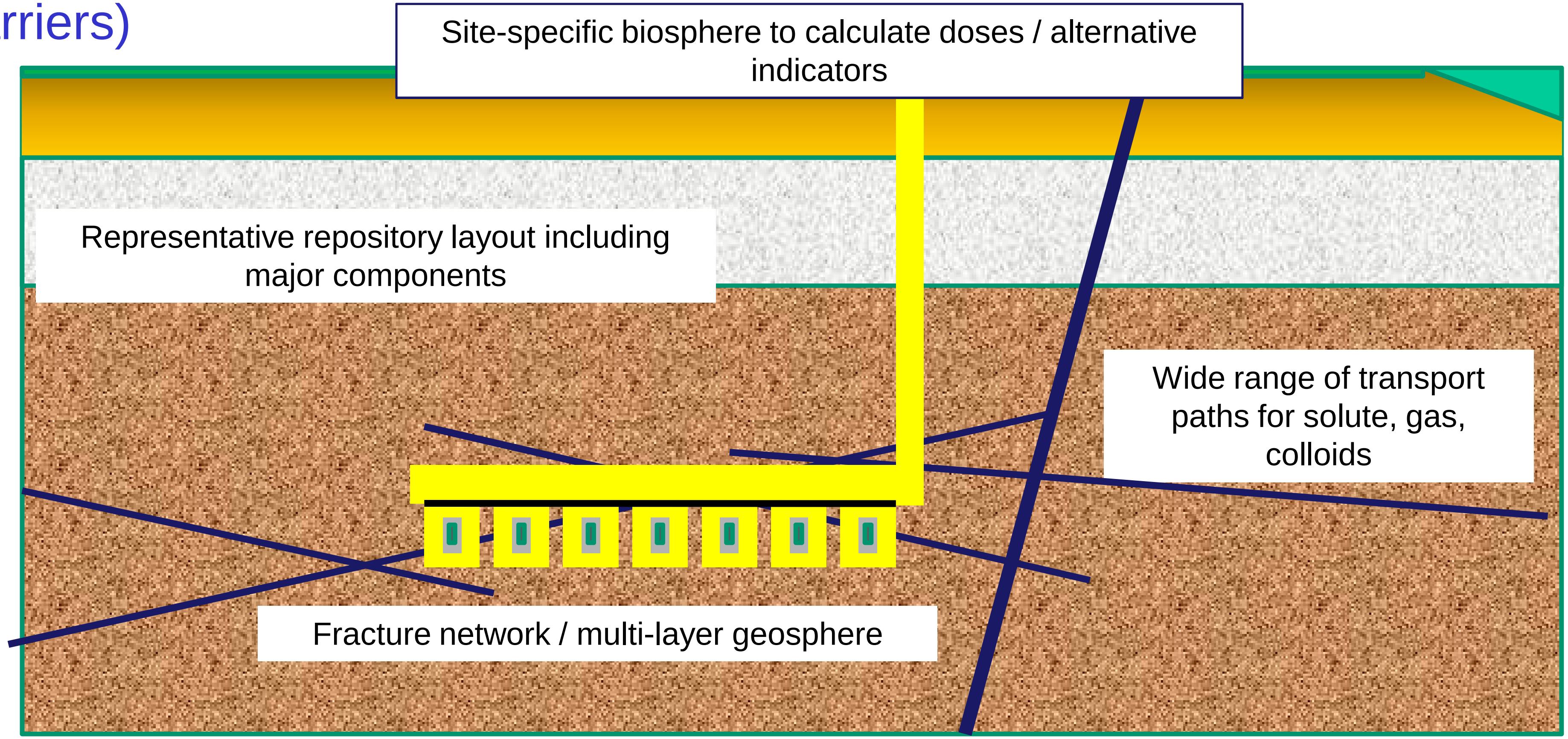
Safety assessment in the mid '80s

- 1 – 2 D, solved numerically (most parameters time-independent)
- Range of scenarios assessed (semi-)quantitatively
- Output: dose or risk as f(t)



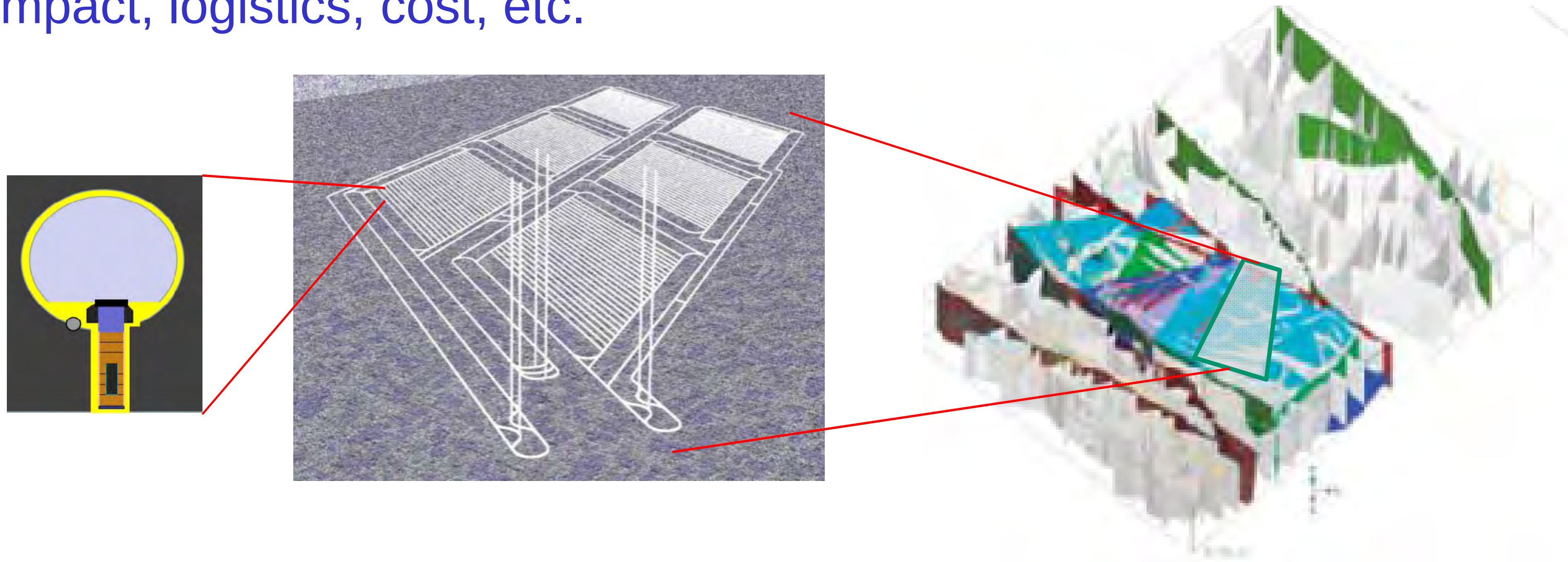
Safety assessment now

- Nested 3 D, solved numerically (some parameters f(t), stepwise)
- Wide range of scenarios assessed quantitatively
- Complex processes considered as perturbations
- Evaluation of operational QA & safety
- Output: dose, risk and alternative indicators (releases and distribution in barriers)



Safety assessment 2020s?

- Fully integrated 3D assessment with all processes represented
- Optimised designs with consideration of all materials present
- Full timeline from initiation of field characterisation to erosion
- Accessible as interactive virtual reality with hyperlinks to all supporting information
- Output: integrated safety (operational & post-closure), environmental impact, logistics, cost, etc.



Evolution of disposal Knowledge Base

1940
1950
1960
1970
1980
1990
2000
2010

key documents

All on paper

Inventory ("pages") of key

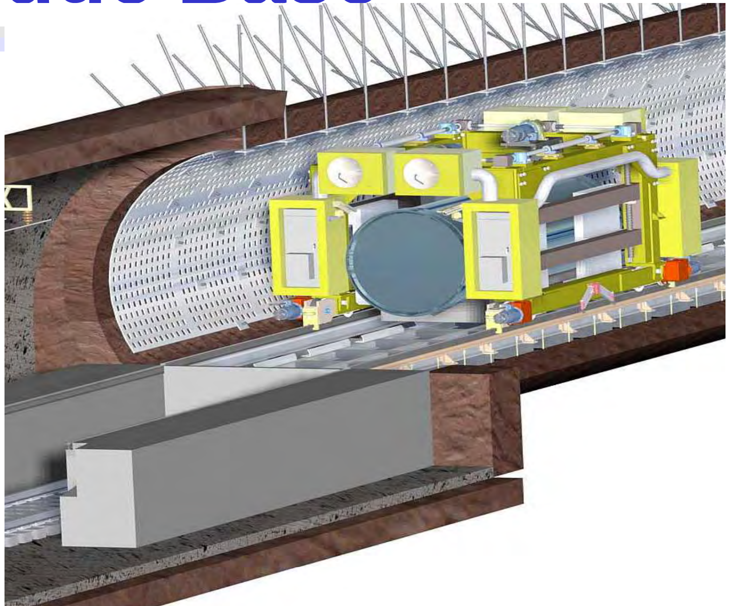
Literature	**Databases**
10^4	**10^4**

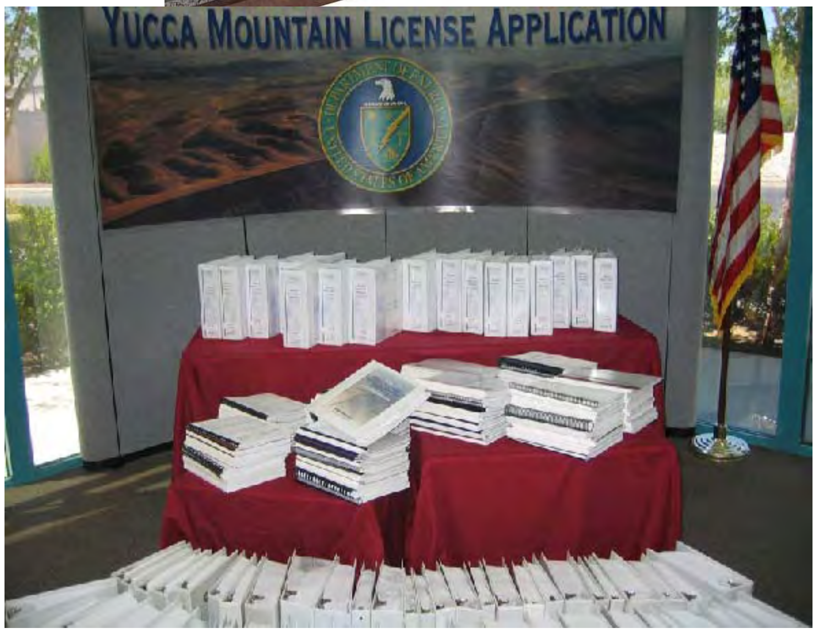
NB 1 "page" ca. 2 kB

"Transuranic waste at the Atomic Energy Commission's nuclear weapons facilities (shown here is Hanford Reservation, circa 1950s) was frequently disposed of in cardboard boxes" US Dept. of Energy

Evolution of disposal Knowledge Base

Year	Key documents	Literature
1940		
1950		
1960		10^4
1970	*All on paper*	
1980	*Most on paper*	10^6
1990	*Most electronic*	
2000	*All electronic*	10^8
2010		





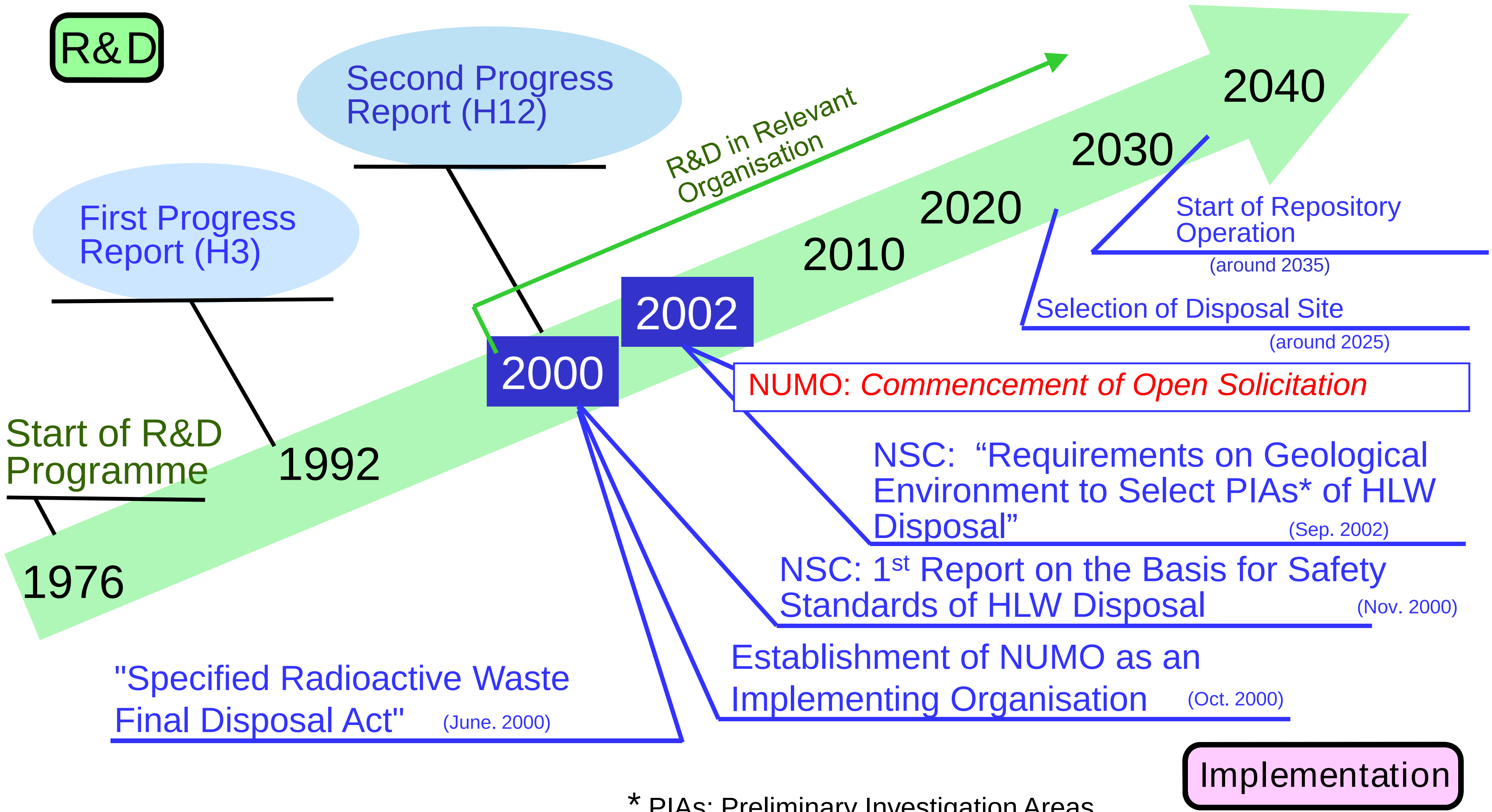
Exponential Growth - KM challenges

- **Extrapolations of exponential growth are dangerous** but, based on 40 years experience, it is difficult to argue that such rates will not continue – which would give:
  - For a repository licensed for operation in 2030, the volume of relevant international *documentation* could be in the order of *10^{11} pages*, supported by 10 - 100 PB of data
  - Licensing for closure in 2090 would require consideration of a rather inconceivable *10^{17} pages of documents*, supported by well over 1000 EB of data
- The YMP website already contains about *10^{7} pages;* for conventional print-out, 100 pages is about 1 cm so this is equivalent to around 1km of printed documentation. The associated raw data, if printed out, would be about 100 times larger.
- Note that *10^{11} pages,* as conventional text, is thus 10,000 km worth with an associated pile of raw data that would stretch to the moon: luckily this will all exist in electronic form – but how can this be managed?

Big Message (1)

Based on the volume of information to be handled, it is no longer a question of whether advanced KMS will be introduced into radwaste management programmes or not – only whether such systems can be developed and implemented before total collapse of conventional approaches!

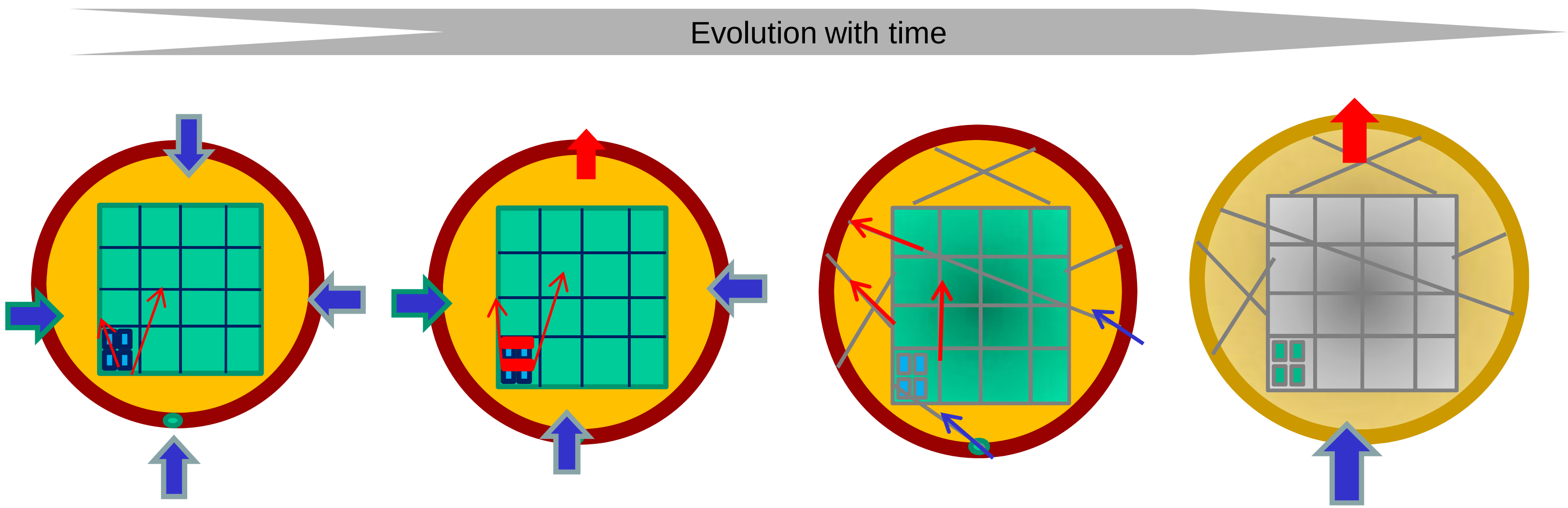
Development of Japanese HLW disposal programme



* PIAs: Preliminary Investigation Areas

Information explosion in R&D supporting geological disposal in Japan

- The size of the first integrated PA (H3) was ~ 400 pages, by the second PA (H12), 9 years later, this had expanded to ~ 2,000 pages.
- One of the greatest difficulties was integrating the huge amount of supporting information/data on geological environments, engineering and safety assessment.
- In the future, the volume of data will explode as more synthetic modelling includes high resolution in 3D and explicit representation of time evolution of entire HLW / TRU repository systems.



Special issues related to the Japanese programme

- Volunteering approach – uncertainties in timescales, site properties (potentially complex geology) and appropriate repository designs
- Tight schedule for early stages of site characterisation, which could run in parallel at several sites
- Considered for both HLW and “TRU” (separate facilities or co-disposal)
- Shortage of experienced staff and marked age bulge passing through all key organisations
- Commitment to openness and transparency

The team with 30 years experience!

HLW / TRU integrated PAs
- support / coordination / review

1980

1985 ← **1985 - Projekt Gewahr**

1990 ← **1991 - H3**

← **1993 - Kristallin-1**

1995

2000 ← **1999 - 1st TRU report**

← **2000 - H12**

← **2002 - Entsorgungsnachweis**

2005 ← **2005 - H17**

2010 ← **2010 – H22**

Big Message (2)

The Japanese decision to rapidly move into advanced KM was driven by the boundary conditions of the national programme. In particular, imminent loss of many experienced staff as they retire leaves only a small window to capture tacit knowledge (common problem throughout the nuclear industry).

"Next Generation" KMS - Challenges

- Development of a conceptual KMS is challenging in itself
  - should not simply be a passive tool to archive and disseminate information
  - requires internal analytical facilities to:
    - synthesize and integrate material from a diversity of sources
    - identify trends and inconsistencies
    - produce feedback to the data producers
  - should replace many of the functions of the network of peer reviewers and expert advisors who currently carry out such work
- A further problem lies with:
  - establishing a strategy to produce a functioning system which has the capacity to respond to a rapidly growing knowledge base
  - flexibility to respond to changing requirements of end-users to ensure that it is adopted by both knowledge-producers and knowledge-users

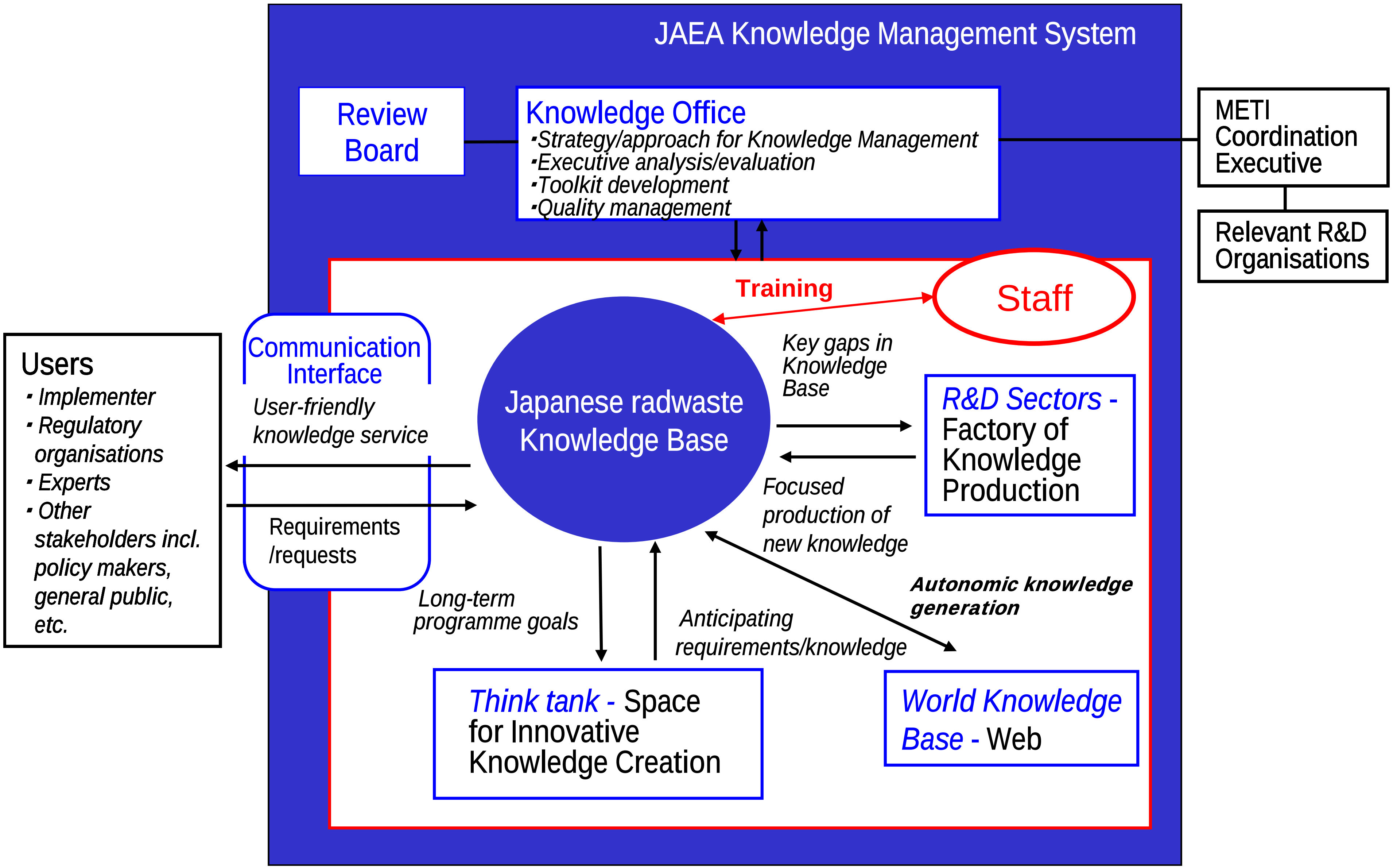
“Next Generation” KMS

- Novel knowledge management tools utilising advanced electronic information management technology are essential to handle the vast quantity of information involved. The JAEA concept envisages:
  - autonomic systems will perform many of the information processing functions, helping ensure that required knowledge is accessible to all stakeholders and that gaps can be identified and supporting R&D prioritized
  - facilitate use of the core of “neutral” scientific and technical knowledge by both the implementer and the regulator
  - flexibility is built into the system, to allow it to be restructured to match the user’s needs or even interfaced directly to a formal requirements management system
- Appears feasible based on experience in relevant areas such as **expert systems**, **artificial intelligence**, **neural networks**, **web-based agents** and **bots**, etc.

Big Message (3)

The problem identified is so fundamental that modification of conventional approaches offers no chance of solving it – a complete paradigm shift is required, which emphasises structured processes and use of advanced IT and KE methodology.

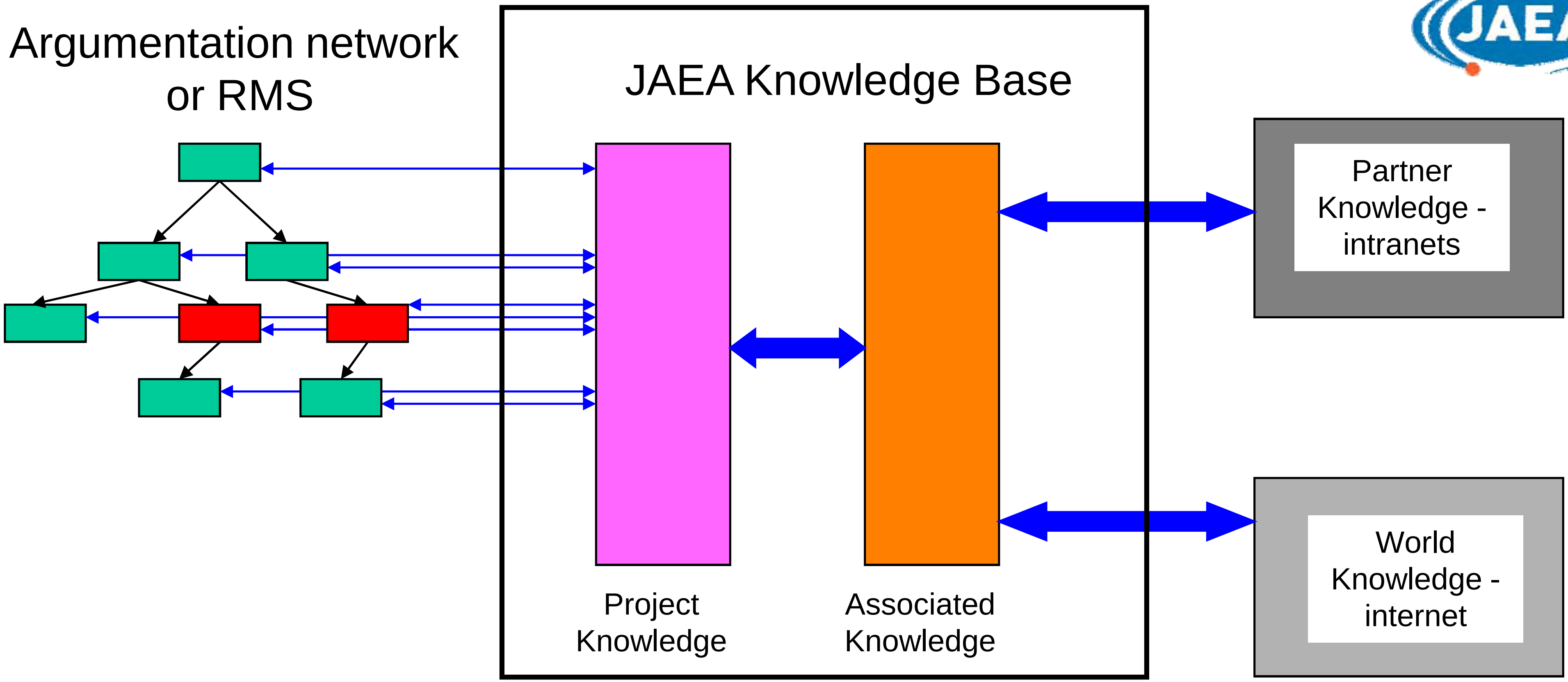
Structure and components of the KMS



Critical KMS components

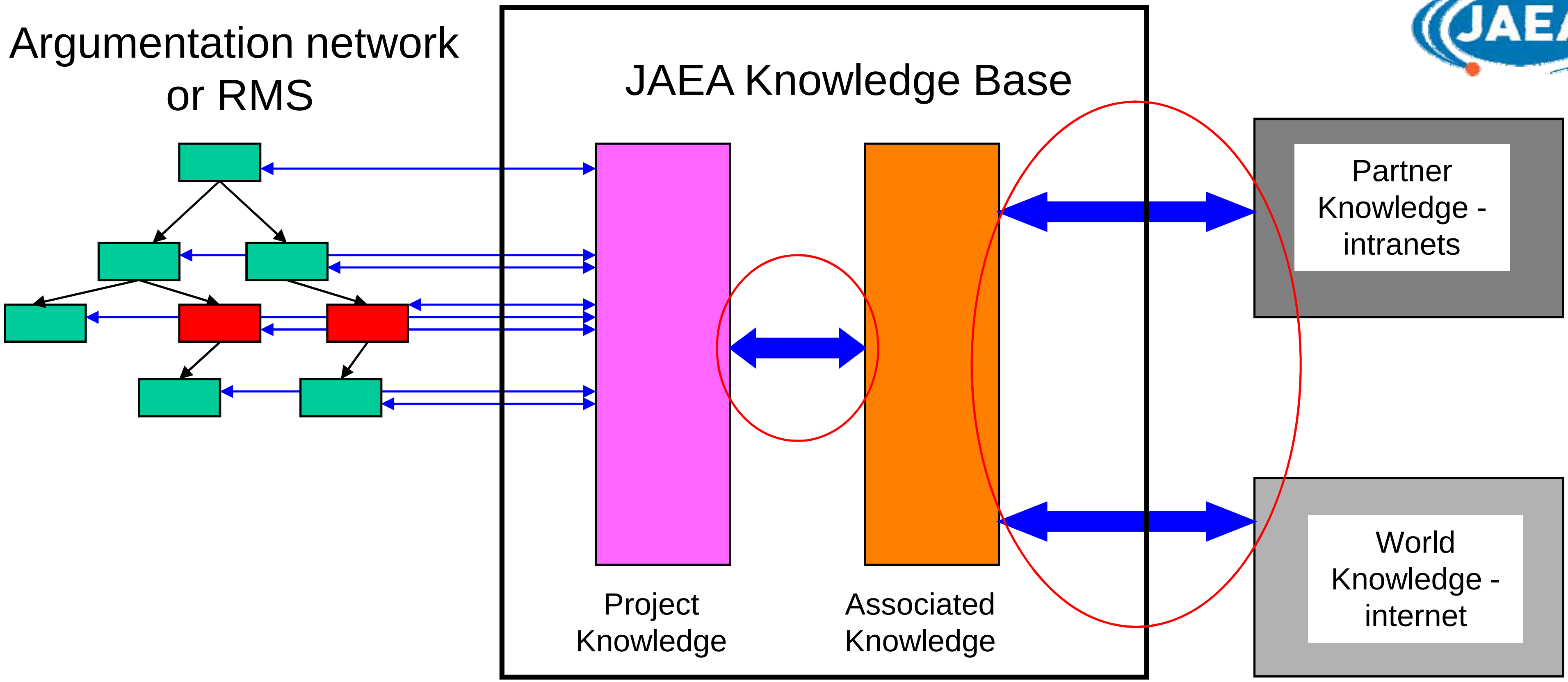
- The Knowledge Base (KB) and associated archiving and maintenance tools
- Knowledge acquisition technology (for both explicit & tacit knowledge)
- Knowledge manipulation technology (for autonomic processing, quality checking, trend analysis, etc.)
- Flexible and user-friendly communication interface
- Training and transfer of tacit knowledge
- Executive coordination: including monitoring of progress and user feedback, quality management and strategy development (including initiatives to anticipate important future developments in technology or project boundary conditions)

Next presentation



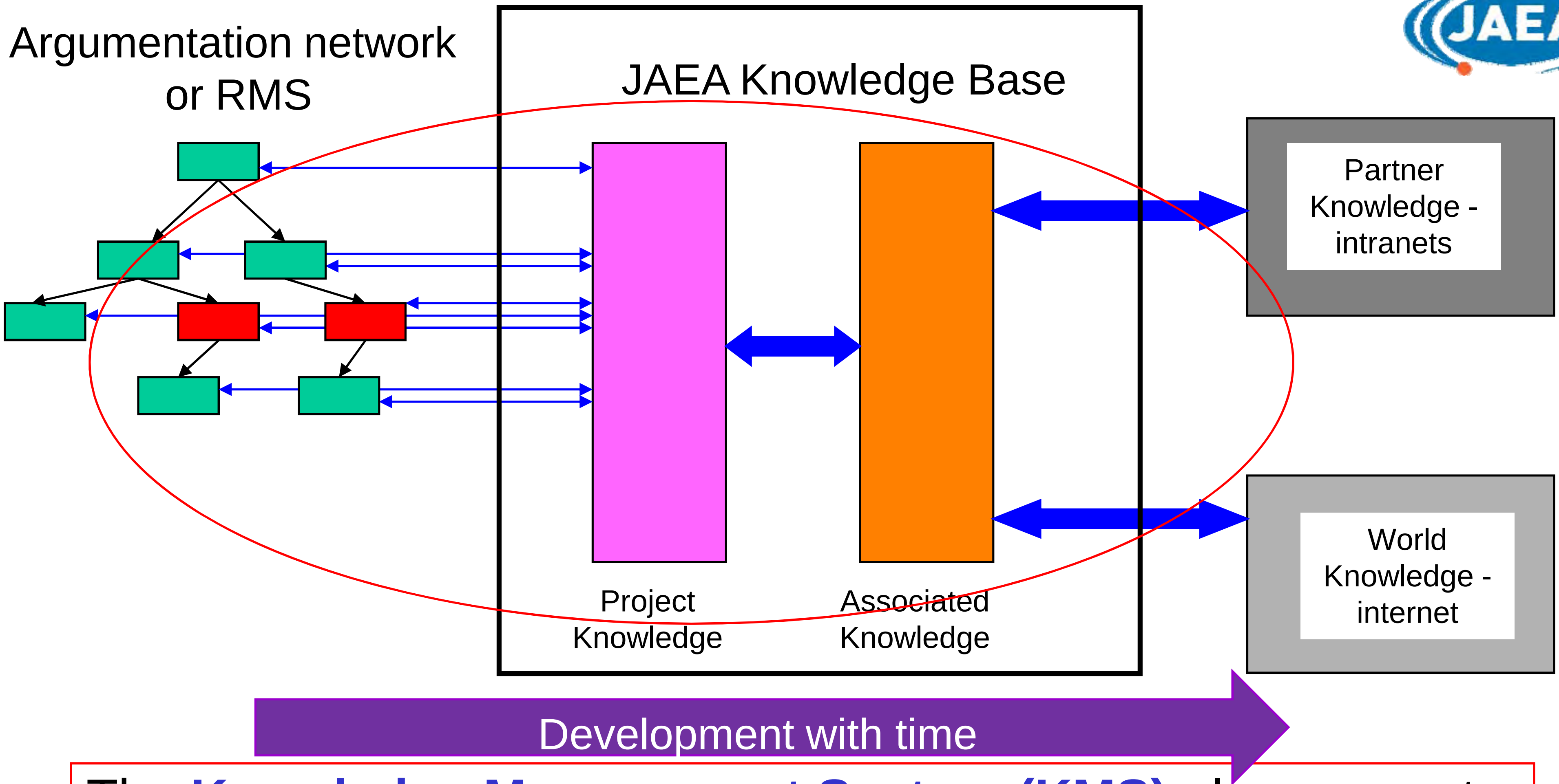
The **Knowledge Base (KB)** does not need to be rigorously structured;

- Standardised vocabulary (ontology) allows application of smart search engines
- Requires rigorous file management procedures and robust security



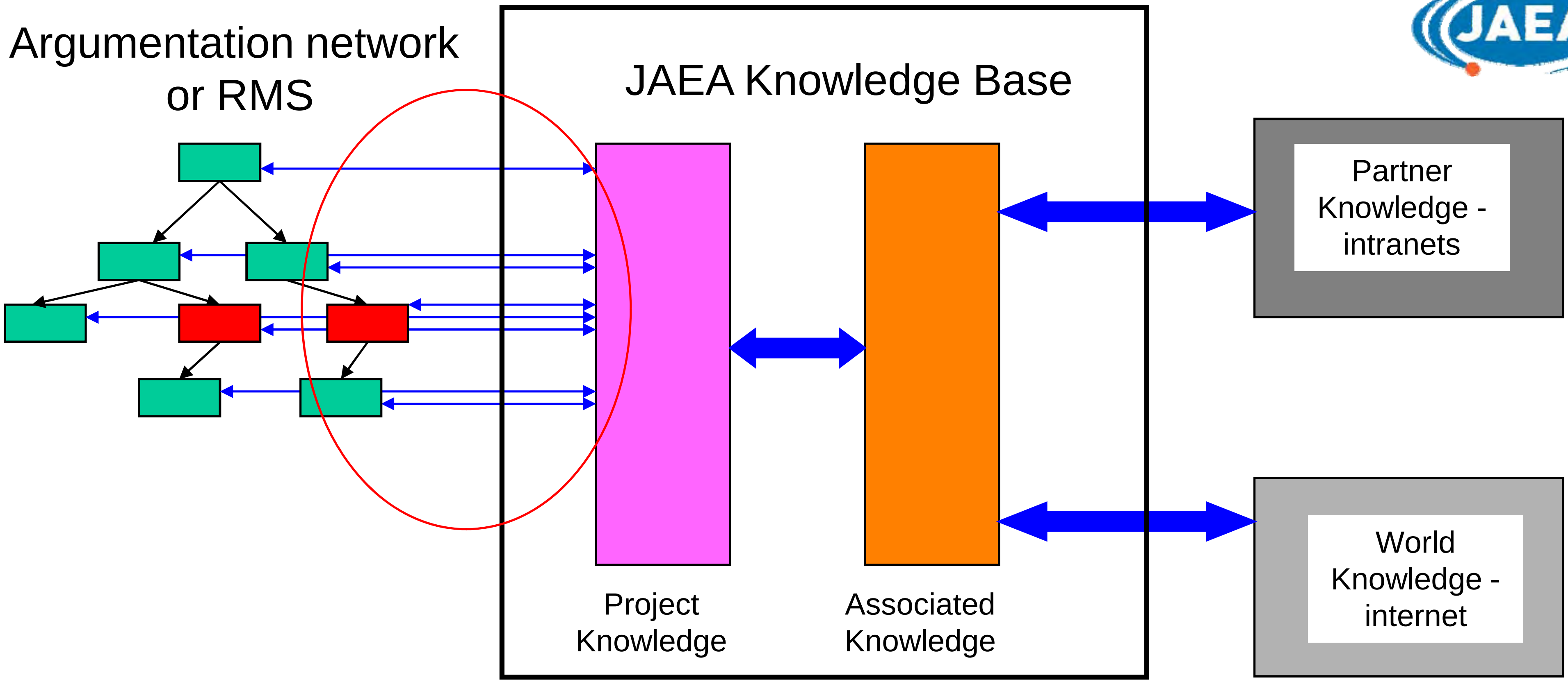
Smart search engines play a key role;

- Allow practical access to huge volumes of data
- Can incorporate functionality, providing autonomous quality checks, synthesis, identification of knowledge gaps, report generation,...



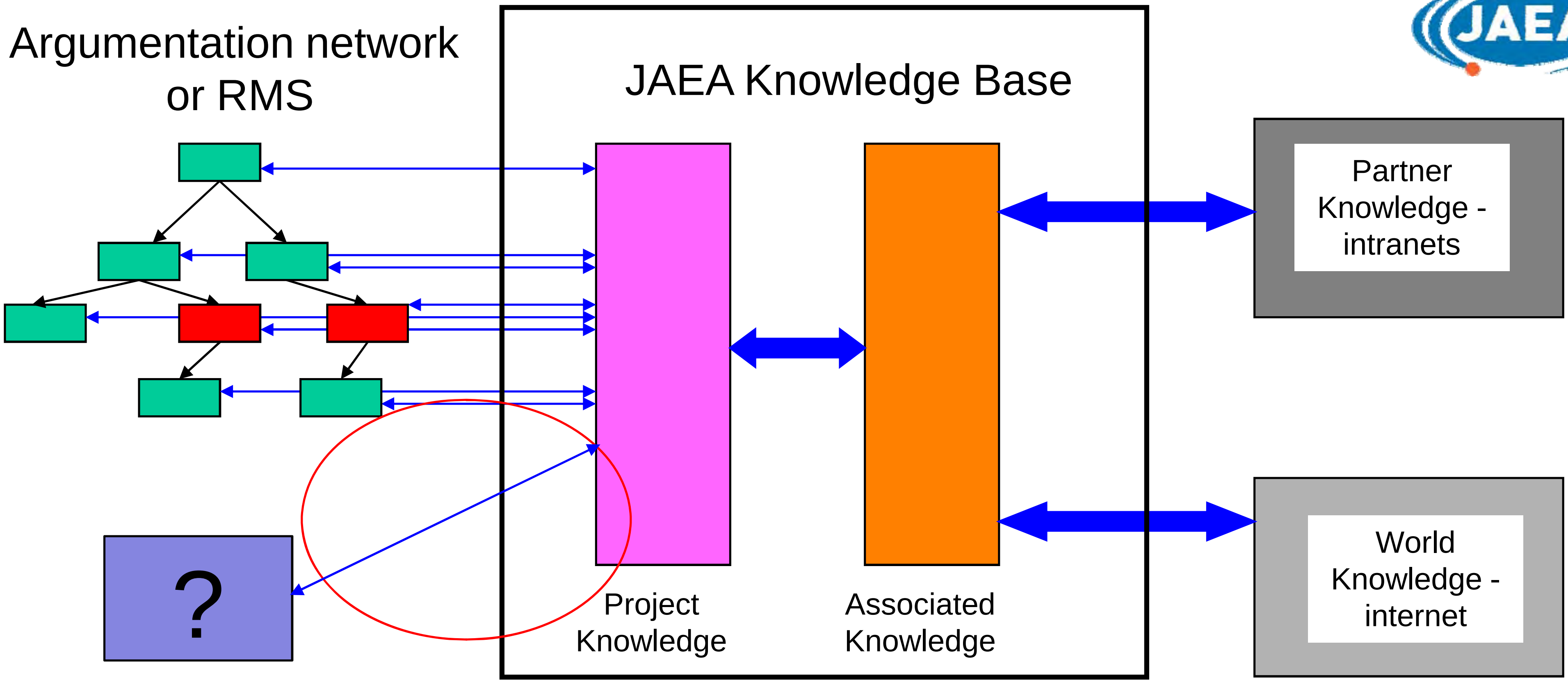
The **Knowledge Management System (KMS)** also serves to

- Maintain, update and facilitate access to the KB (automated as far as possible)
- Establish effective interfaces to Knowledge producers & users (utilising advanced communication tools)
- Ensure development of the tacit knowledge required to perform tasks that cannot be automated (e.g. decision making)

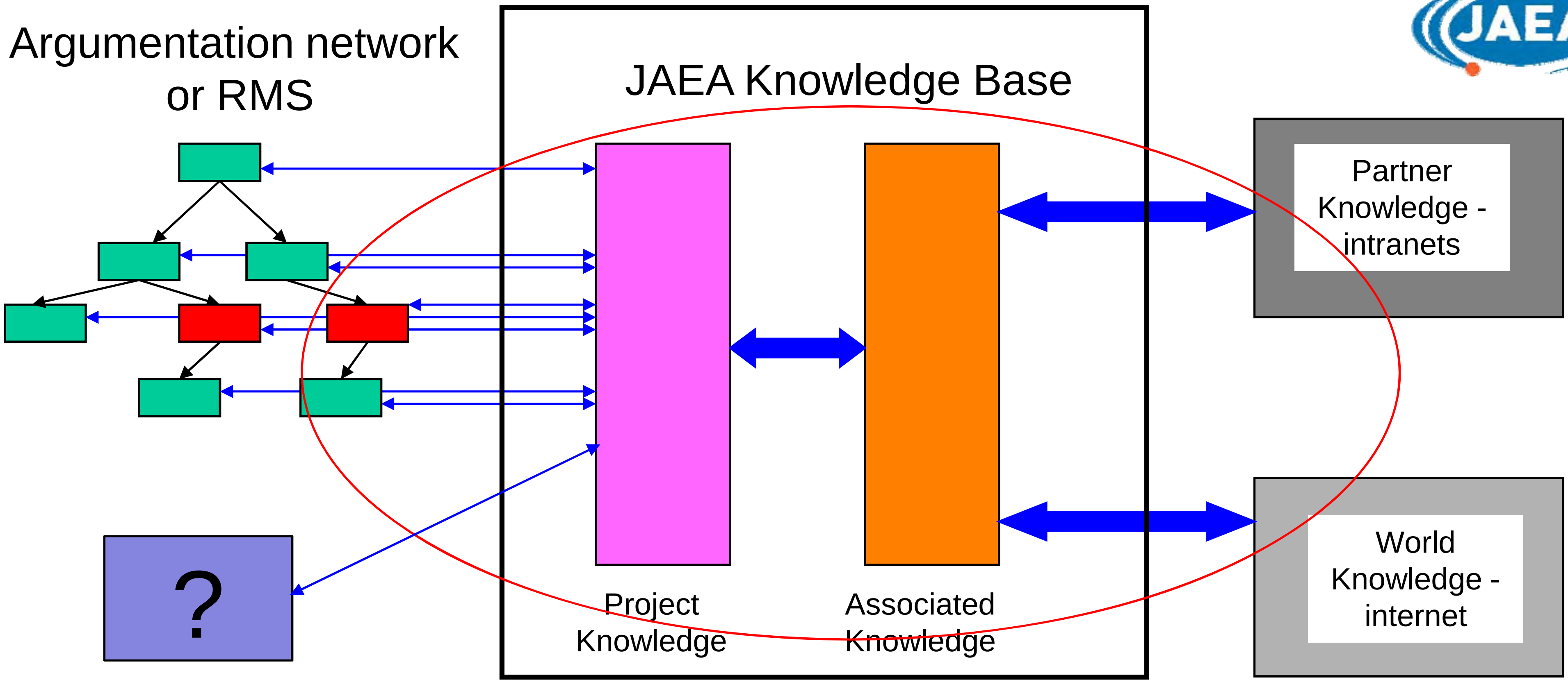


KMS application is driven by the needs of users (including knowledge producers), may be formally defined:

- An interface to an established Requirements Management System (RMS)
- An argumentation network flexible enough to fit the needs of all users



KMS application must, however, also have the flexibility to rapidly and effectively respond to any questions by establishing dialogue with stakeholders – which provides challenges for both communication interface development and fundamental knowledge management



- **The "Intelligent Assistant"** is the integrated toolkit for
  - Compiling explicit knowledge - **knowledge mining tool**
  - Compiling tacit knowledge - **expert system tool**
  - Autonomic knowledge manipulation – **archiving, quality testing, synthesis, integration and documentation tools**
  - Knowledge presentation – **visualisation tool**

Feasibility of an “intelligent assistant”

In principle, feasible based on the observations that:

- Most of key information for repository projects
  - already available electronically and accessible via internet / intranet systems
  - reasonable to expect effectively 100% coverage in the near future
- Content-recognition & cross-referencing systems
  - increasingly sophisticated
  - allow relationships between documents and any form of datasets to be defined in much more detail than traditional approaches
- Autonomic data-mining techniques involving network agents
  - currently an area of very rapid progress
  - allows much of the information gathering, sorting and compilation processes to be automated
- Combination of expert systems with autonomic learning approaches (e.g. based on neural networks)
  - allows, at least in principle, many of the key processes involved in knowledge management – collation, synthesis, review, etc. – to be automated

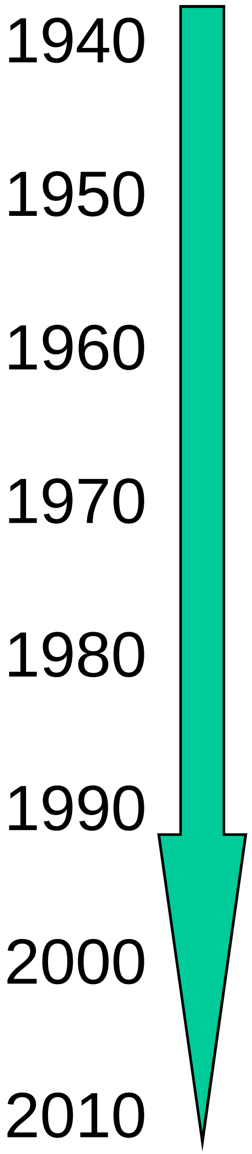
Big Message (4)

The developments envisaged are ambitious but appear feasible based on current technology. The individual components needed all exist – they have just never been combined and implemented in the manner planned.

A special concern - tacit knowledge

- Most KM applications noted above focus on **explicit** knowledge - that which can be readily documented
- Just as important is **tacit** knowledge - information and experience which is contained in the heads of senior staff and plays a key role in planning and decision making - particularly in pragmatic areas of multidisciplinary projects
- Tacit knowledge has tended to be managed in the past via training / apprenticeships / on-the-job experience transfer, but this is now critical in many programmes due to retirement of staff who played unique development roles
- Special training and mentoring projects may be valuable, combined with more speculative, novel approaches (e.g. based on e-learning supported by expert systems)

Problem definition



In the early days, small groups of mainly young staff with large supporting resources developed experience “by doing it”:

- background knowledge was very limited
- systems were relatively simple in terms of materials and mechanisms
- mistakes could be (and were) made (low public concern, relaxed safety requirements)
- a few people covered many technical areas in different projects (encouraged generalists)

Problem definition

1940

1950

1960

Now, large organisations with boundary conditions set by:

- huge volume of background knowledge
- systems more complex in terms of materials and mechanisms
- mistakes must be avoided (high public concern, strict safety requirements)
- little opportunity for involvement in diverse technical areas in different projects (encourages specialists)

1970

1980

1990

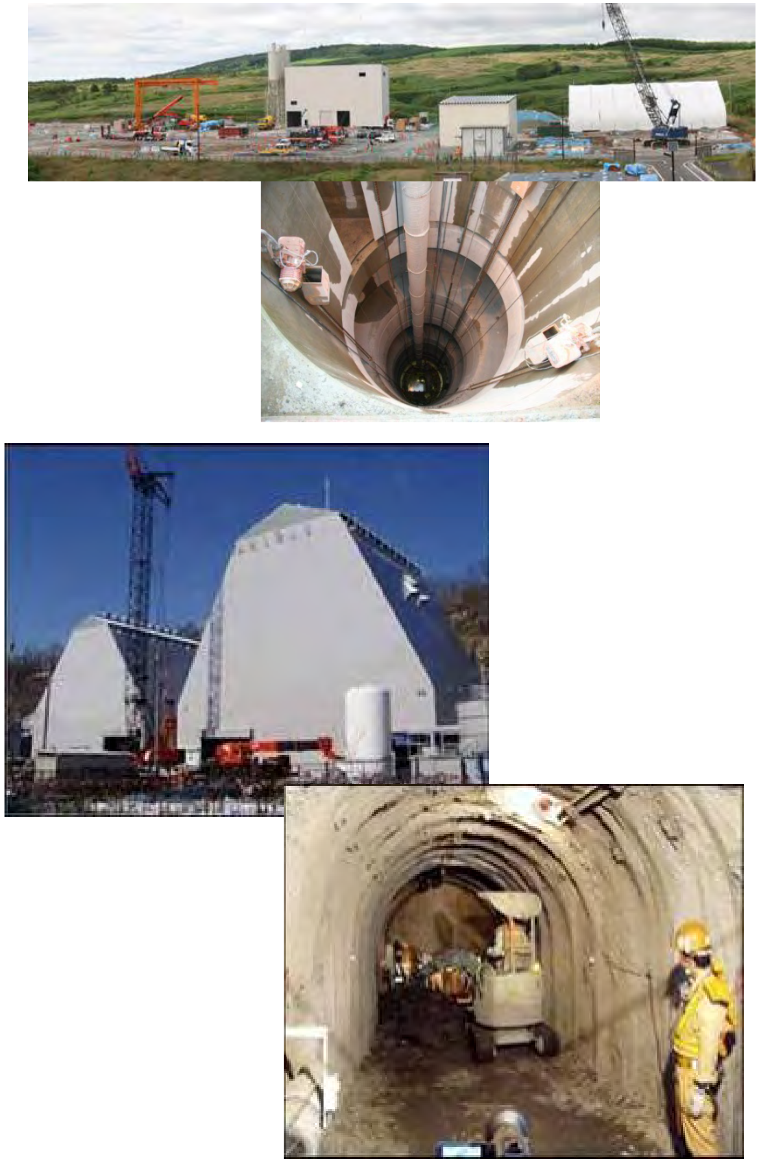
2000

2010

Training and experience transfer

In the past rather ad-hoc, but needs careful planning in the future to maximise output from limited resources:

- special training based on international infrastructure (e.g. ITC), complemented by tailored courses on key topics of national relevance
- plan projects (especially interdisciplinary / international studies) to maximise experience transfer to young staff
- projects in URLs and natural analogue studies can be particularly useful
- use of mentors to allow junior staff to gain experience in complex projects



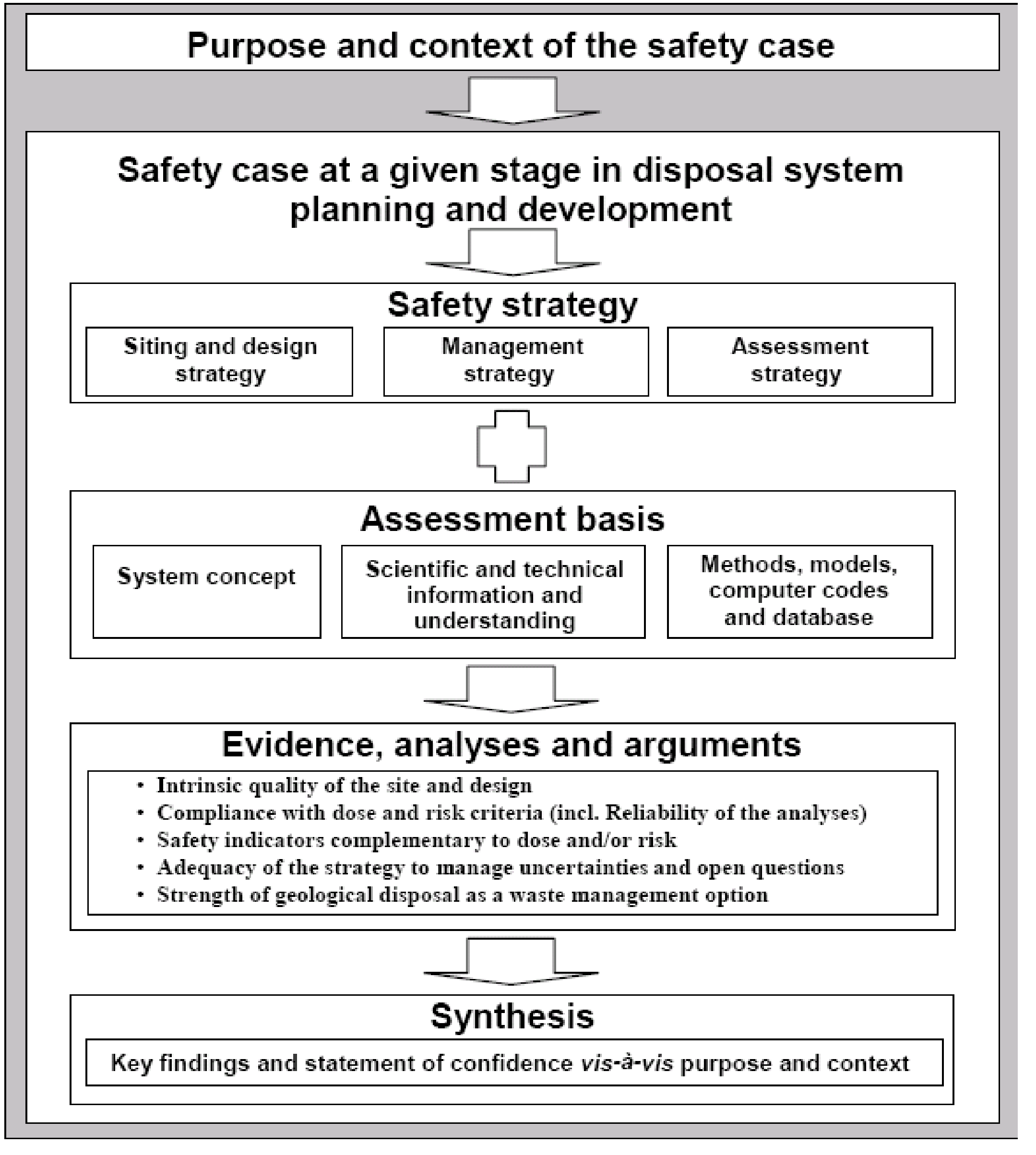
Big Message (5)

The most important resource of any radwaste organisation is its expert manpower. Specialists can be trained using existing structures, but generalists must be cultured – using a combination of tailored training and focused “on the job” transfer of experience from mentors. Project planning must take this critical goal into account!

Ensure applicability

- Fundamental role for all users is related to a **safety case**:
  - Developed by NUMO, on the basis of the support provided by knowledge producers
  - Reviewed by the regulators and particular stakeholder groups, facilitated by the agreed structures and databases that the KB contains
  - The focus for discussion with other stakeholders, and decision-makers, who can access supporting information in as much detail as they desire

Relationship between key safety case elements (NEA, 2004)



Safety Case as "Social Knowledge"

- *To have confidence is to have reached a positive judgement that a given set of conclusions are well-supported (OECD/NEA,1999)*
- *The safety case is an integration of arguments and evidence that describe, quantify and substantiate the safety, and the level of confidence in the safety, of a geological disposal facility (IAEA/NEA, 2006)*
- Clearly the safety case is not a simple collection of information. It provides arguments and evidence to support confidence on safety of geological disposal, and is intended to influence judgment, behaviour and attitude of various stakeholders

National context

- The dominant form of knowledge in the West is explicit knowledge, *e.g.,* documents, manuals, and computer databases, which can be readily transmitted between individuals formally and systematically
- The Japanese, on the other hand, see explicit knowledge as just the tip of the iceberg. They view knowledge as primarily tacit, something which is highly personal and deeply rooted in an individual's action and experience
- Danger of emphasising the tacit knowledge alone, however: can fall into "group think trap" or situation where expertise is regarded as an untouchable black box

Principles 1 – Miyamoto Musashi, 1645: Go Rin No Sho

1 Do not think dishonestly

2 The way is in training

3 Become acquainted with every art

4 Know the ways of all professions

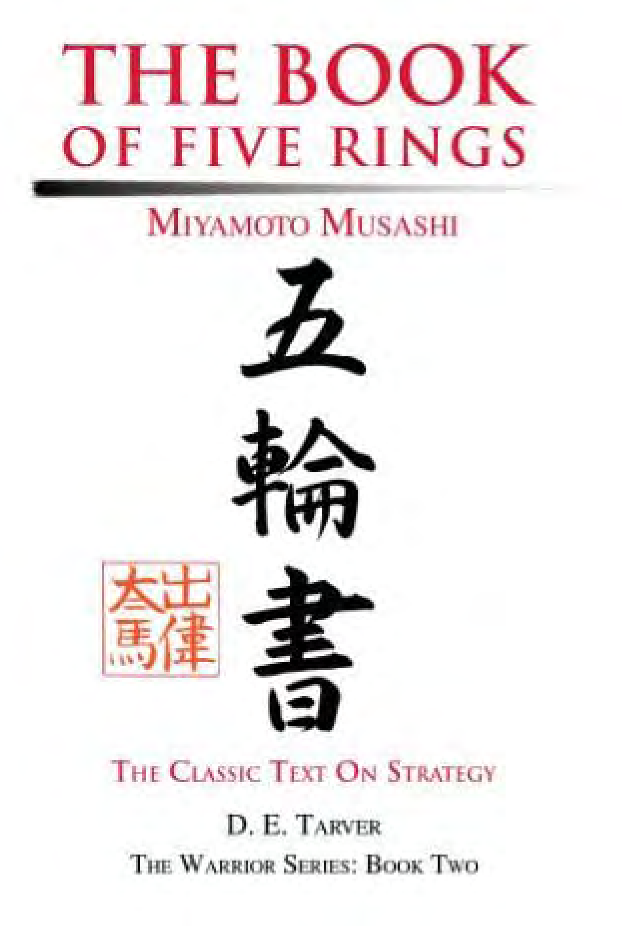
5 Distinguish between gain and loss in worldly matters

6 Develop intuitive judgement and understanding for everything

7 Perceive those things which cannot be seen

8 Pay attention even to trifles

9 Do nothing which is of no use



Principles 2 – NUMO, 2004: TR-04-03

1 Plan pre-emptively

2 Keep it simple

3 Use robust design

4 Integrate safety & quality management

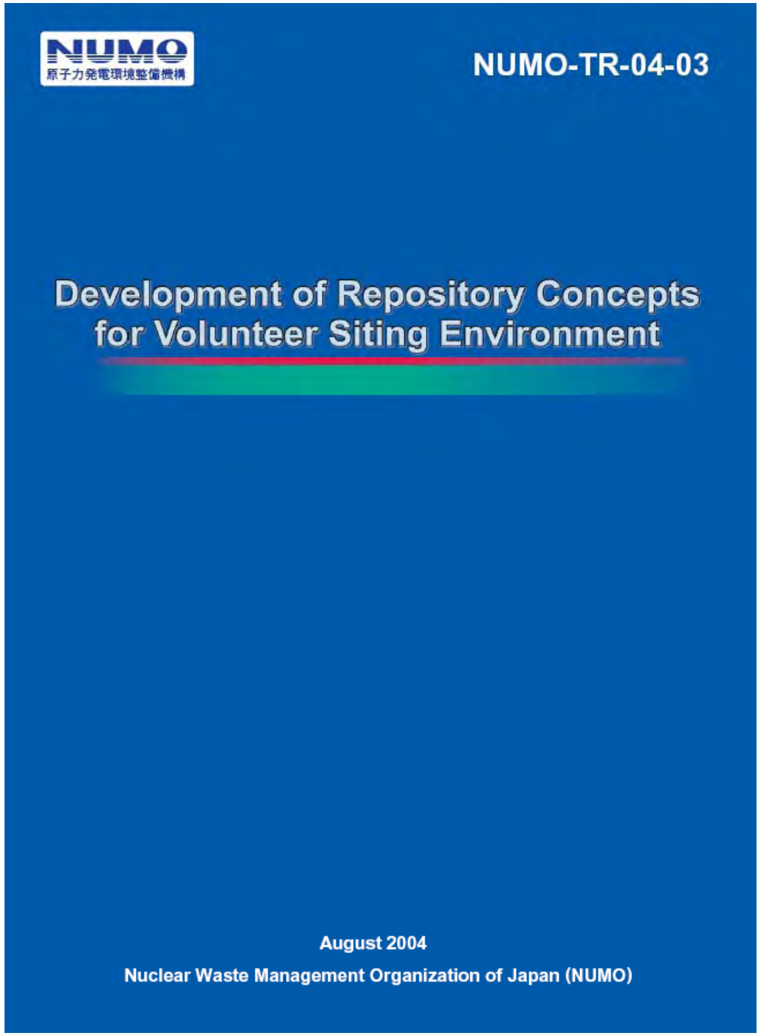
5 Use operational zoning

6 Minimise degradation

7 Consider human factors

8 Involve stakeholders

9 Consider economic constraints


NUMO 原子力発電環境整備機構

NUMO-TR-04-03

Development of Repository Concepts for Volunteer Siting Environment

August 2004

Nuclear Waste Management Organization of Japan (NUMO)

Practical implementation

- **Principles are fine, but tricky to carry out in a transparent manner**
- **Formalisation of processes and, in particular, the decision-making procedure can explain and allow consensus on the inevitable trade-offs required to develop a programme that balances competing requirements**
- **General approaches to solution of such problems are known – but few are as complex and multi-dimensional (multi-disciplinary) as radwaste disposal!**

Coordination & leadership

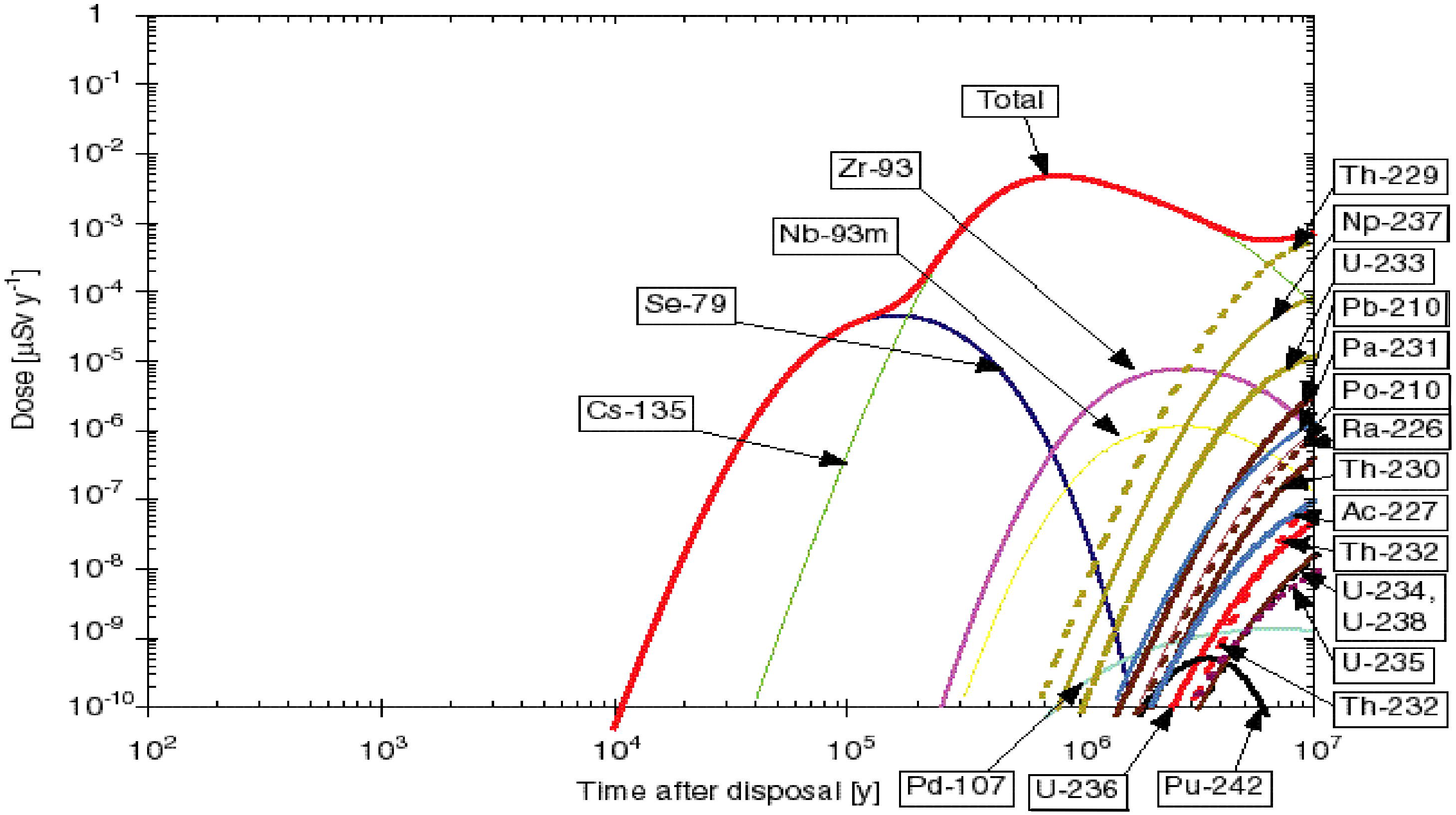
- Topics normally found in “project management” handbooks, but taboo in “hard science” projects
- Nevertheless, critical for a project that is pushing the leading edge of technology and is developed with a perspective in the order of a hundred years or so
- Executive coordination is essential to:
  - monitor progress and feedback to ensure that output is appropriate to all users (implementers and regulators, data inputers and outputers, other stakeholders)
  - assure strict quality management, as this will eventually be used to support licensing decisions for repository projects
  - strategy development (given the time frame, needs initiatives to anticipate important future developments in technology or project boundary conditions)

Big Message (6)

Any KMS development project must have clear applications, deliverables and milestones. The safety case provides a top level focus for all of the work that is carried out in national programmes (NB includes both technical and socio-political issues as defined in Japan) and allows knowledge creation requirements to be prioritised

QUALITY MANAGEMENT

Has to be assured at all levels: from data production to final documentation: results to 10 Ma and covering 10 orders of magnitude are useful for PA experts – but will confuse everyone else!



Quality management

- Agreed to be essential, but has been the bane of many programmes when inappropriately applied
- Can also be focused by the safety case – level of quality required is related to the contribution to the safety case:
  - High quality required for critical arguments (e.g. dimensions of host rock are well defined)
  - Lower levels acceptable for general supporting information (e.g. Thermal conductivity of overlying formations is characterised)
- Essential to establish credibility of implementers, regulators and supporting R&D organisations; formal certification may be necessary, but is certainly not sufficient as quality of product (often set by tacit knowledge) is more critical than adhering to procedures (classic QA of explicit knowledge)

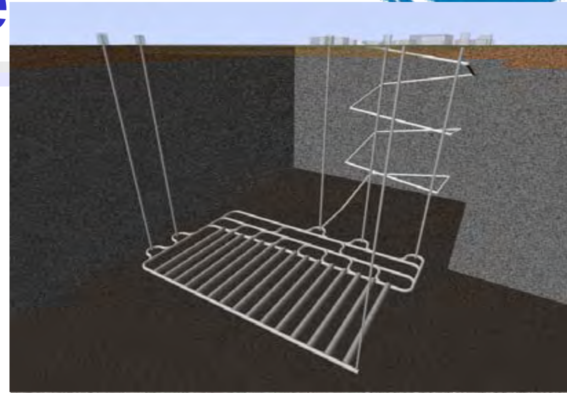
Big Message (7)

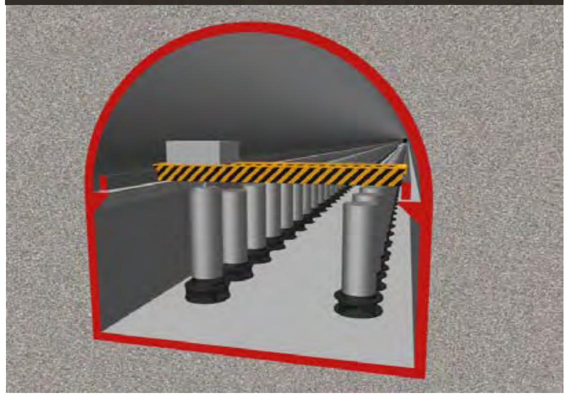
Quality management must be implemented in a focused and effective manner that encourages all those involved to adopt a quality culture. KM tools should minimise the effort of QA while making benefits clear to users.

Strategic planning – the 100y perspecive

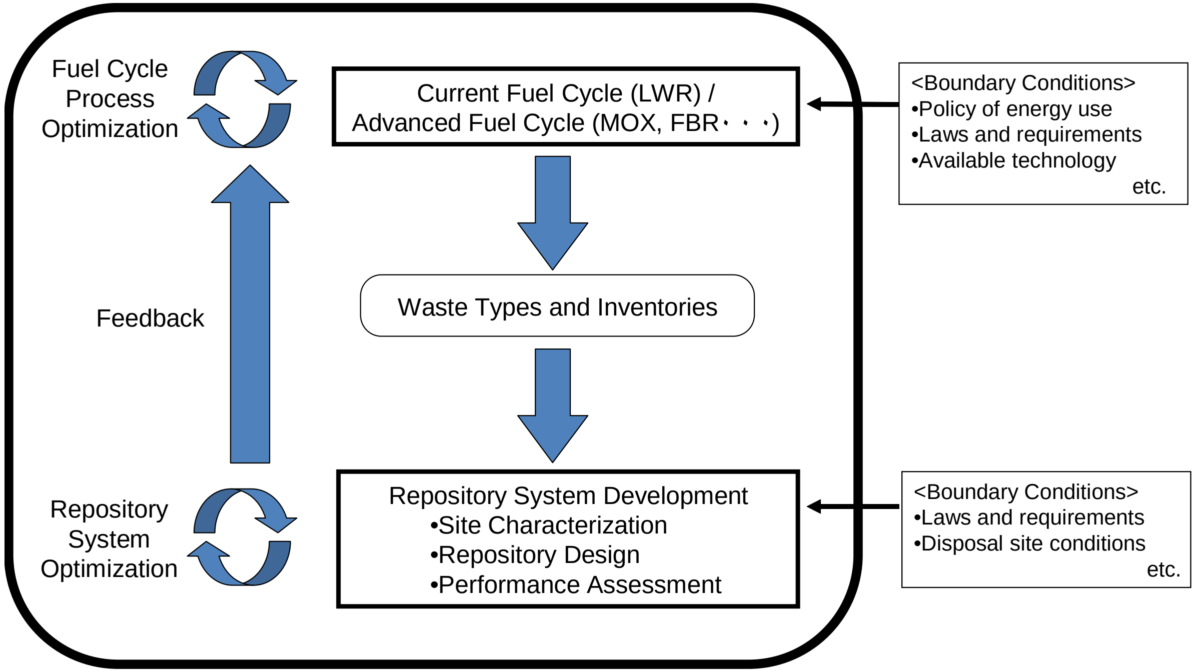
- *Planning must focus on key milestones* in the Japanese waste disposal programme *and then work backwards* to identify R&D priorities based on estimated production times (which can be many decades). Such milestones lie 50-100 years in the future and, in order to specify them, the technological – and social – environment at this time must be specified.
- ***Predicting the future is inherently impossible – but approaches used by other industries to scope possible future scenarios will be tested to determine their ability to develop credible scenarios for utilisation in JAEA's projects***.

Thinking about the future





- Critical role of the Knowledge Office – providing anticipation of future requirements and boundary conditions
  - Waste arisings from future power plants
  - Future socio-political conditions
  - Next generation repository designs
  - Advanced PA methodology



Output

- Both the studies supporting the advanced fuel cycles and the "Think Tank" initiative provide novel perspectives on the planning basis for the KMS
- Even if output must be treated with caution, such approaches are valuable in providing a perspective on the timescales over which repository planning is carried out

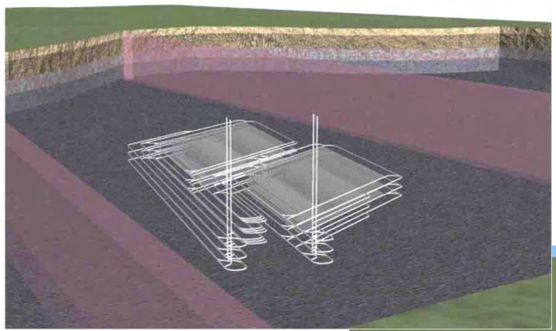
Big Message (8)

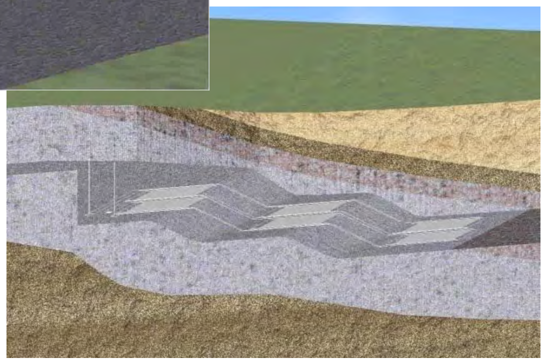
Long-term planning can only be carried out with an appreciation of the inherent volatility of project boundary conditions (both technical and socio-political): studies of advanced fuel cycles for the late 21st century and exercises such as the JTT can introduce such perspectives to specialists and younger staff.

Critical applications

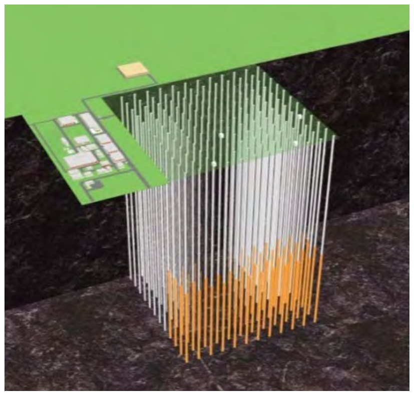
- Although radwaste management work components are strongly coupled, particular areas are obvious priorities for advanced KMS application
- Due to the volunteering process, the development of tailored designs and the assessment of their safety is inherently more complex than in programmes with nomination of particularly favourable sites – pragmatic design and realistic assessment must be used to determine if specific sites are "good enough"
- The stepwise increase in system understanding requires flexibility, with iterative evolution of the concept and associated safety assessment
- Hence a subsystem that incorporates all the critical challenges that will arise in safety case development

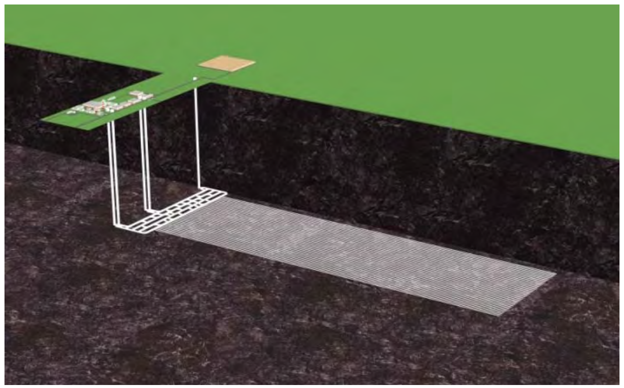
A small selection of the range of RC components

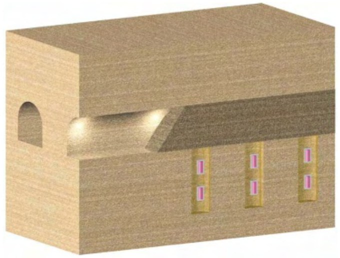




Repository layout



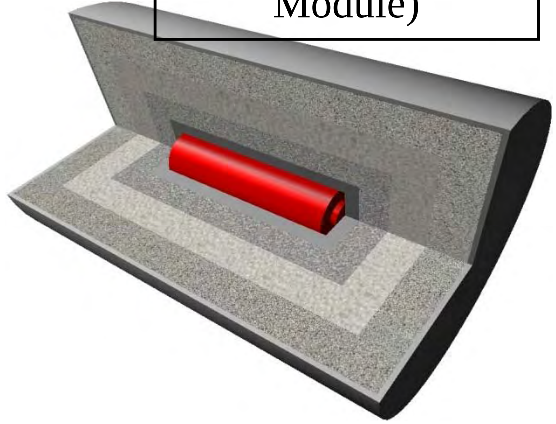


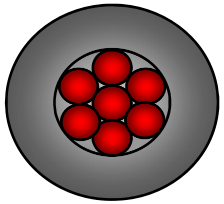


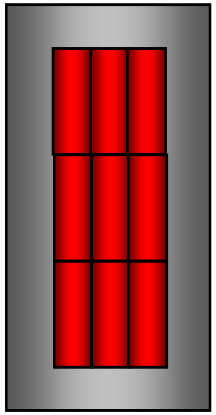
Emplacement / waste package

Vertical multiple emplacement

MCM
(Multi-Component Module)







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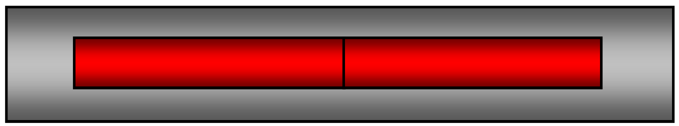
Multiple WP overpacks



Big Message (9)

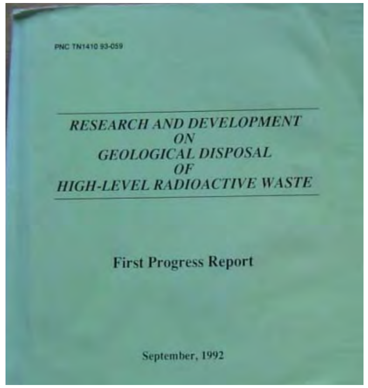
Next generation PA is selected as a topic for testing of KMS technology, not because it is easier, but because it encompasses all the challenges of application to integrated safety case development within a more restricted topical area.

Synthesis – how do we move forward?

- JAEA must provide a status report on its role to support safety case development in 2010 (H22)
- The KMS will be presented as an essential component of this support function
- Given the problems with the information explosion and our commitment to paradigm shift, we are considering a novel approach to such documentation that illustrates many of the principles previously discussed.

The problems of integration & QA

- In the early days, integrated PA was carried out by a small team
- Documentation was in a single report
- QA was very informal, based on internal or limited external reviews
- By the end of last century, extensive report series were required
- Large reports were produced by teams with little overview
- Formal QA introduced, but application limited due to the vast volume of material involved



The solution

- A new approach is required, illustrating how the vast volumes of relevant information can be presented in a user-friendly manner that is accessible to a wide range of stakeholders.
- This should also make quality assurance more transparent and facilitate the complex process of identifying topics requiring future R&D and setting priorities for the use of limited resources.
- Feedback from users will, in turn, be used to improve the structuring of information and the presentation software, so that improved methodology and software tools will be available when they are needed for more critical applications – such as presenting safety cases to support site selection or final licensing of a repository.

The Coolrep idea

The report is produced entirely electronically and is provided on DVD or on the internet in the form of a short, easily readable overview (30 – 50 pages) with extensive hyperlinks to:

- Supporting text providing more detailed technical input
- Full text of key references
- Visual support material, including videos and animations
- All review and QA material
- Relevant web sites

Big Message (10)

JAEA will "put its money where its mouth is" in the next status report (H22), which will not only describe the key KMS concepts required for next generation safety cases but also incorporate these in the document itself.

Conclusions

- A novel challenge for KM is to provide a common scientific and technical basis for all stakeholders in the HLW disposal programme.
- Development of the KMS is a challenge in itself. It seems feasible, however, using state-of-the-art IT and organisational KM tools.
- The KMS tools would free more time for – and ease the process of – top-level synthesis and decision-making, which is essential to efficient, safe, and acceptable repository projects.
- The staff implementing and regulating 21st century radwaste projects will thus have a global overview provided by advanced software, databases and interfaces.
- The challenges will be great but, as this is a concern to all national waste management programmes, it is clearly an area where international collaboration could yield major dividends.

The JAEA KMS:
Design and development, with emphasis on advanced PA methods

Workshop to Review the Progress of the Development of a Knowledge Management System (KMS) and Its Application toward Advanced Performance Assessment (PA)

13-14 November, 2008
Tokyo

Kazumasa Hioki

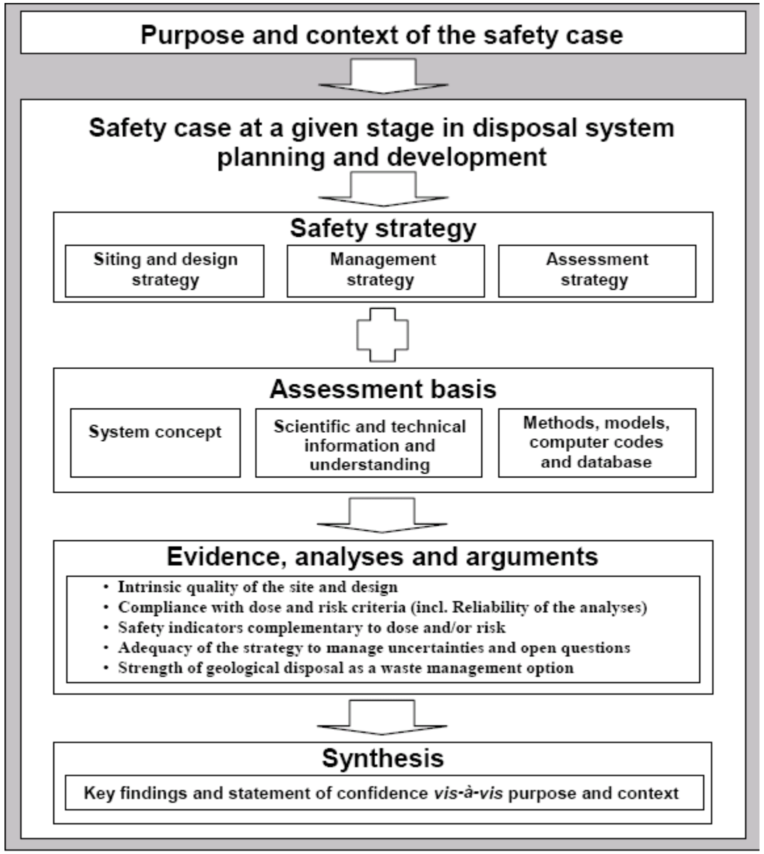
Presentation contents

- Refining the Safety Case
- Focusing Knowledge Creation
- Selecting & applying tools
- Argumentation networks
- Quality management
- Implementation plan
- A look to the future

Refining the Safety Case: emphasis on pragmatism and providing focus for the R&D program

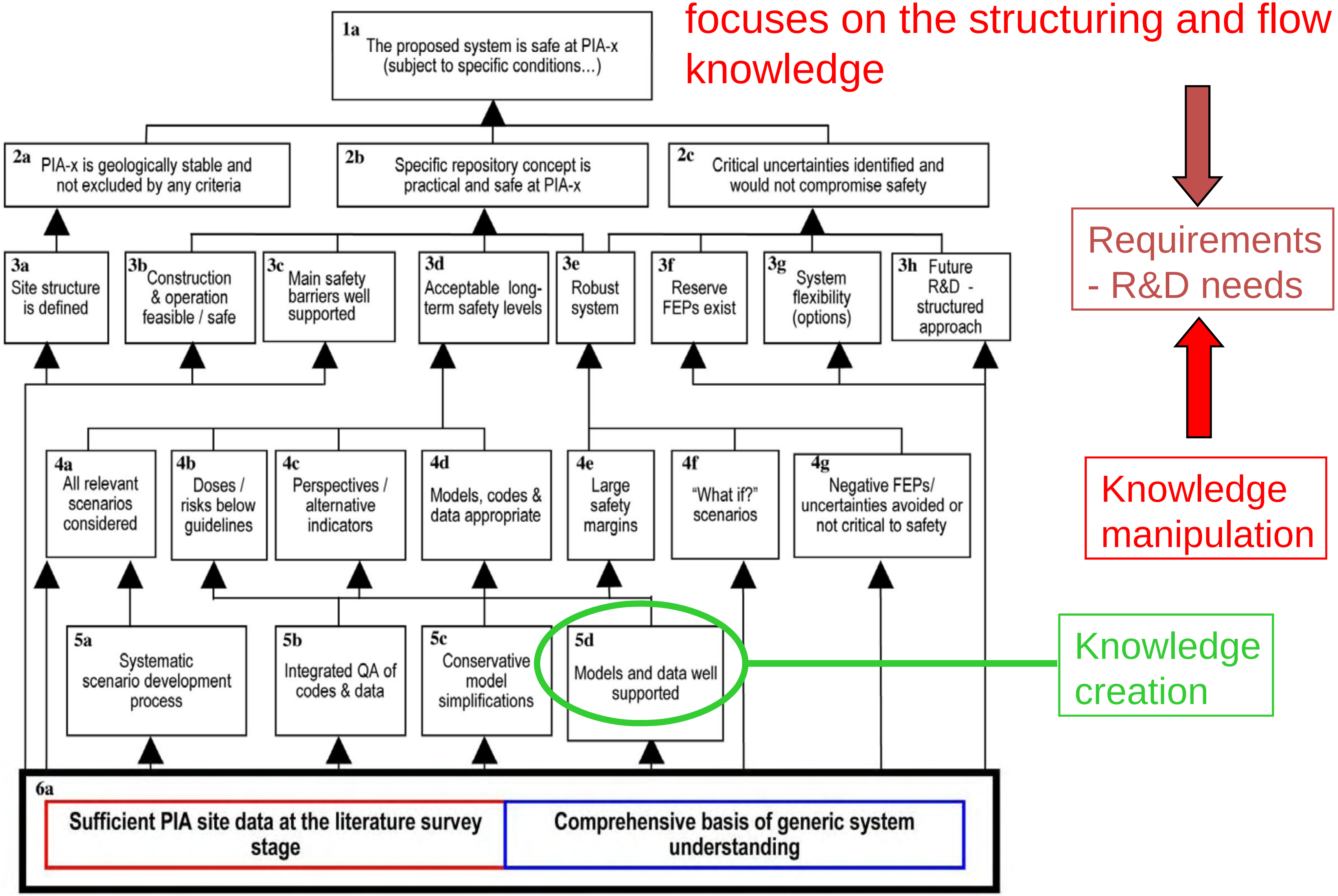
The Safety Case in context

- Demonstration of safety requires more than conventional performance assessment, hence widespread use of "Safety Case"
- Emphasis to date is on post-closure safety; as repositories move closer towards implementation, more aspects need to be considered
- In real life, trade-offs are needed between factors influencing operational safety / practicality, post-closure safety, cost, environmental impact, etc.
- Benefits in widening the definition of "Safety Case" to explicitly account for all the issues to be considered when decisions associated with repository siting or design are made

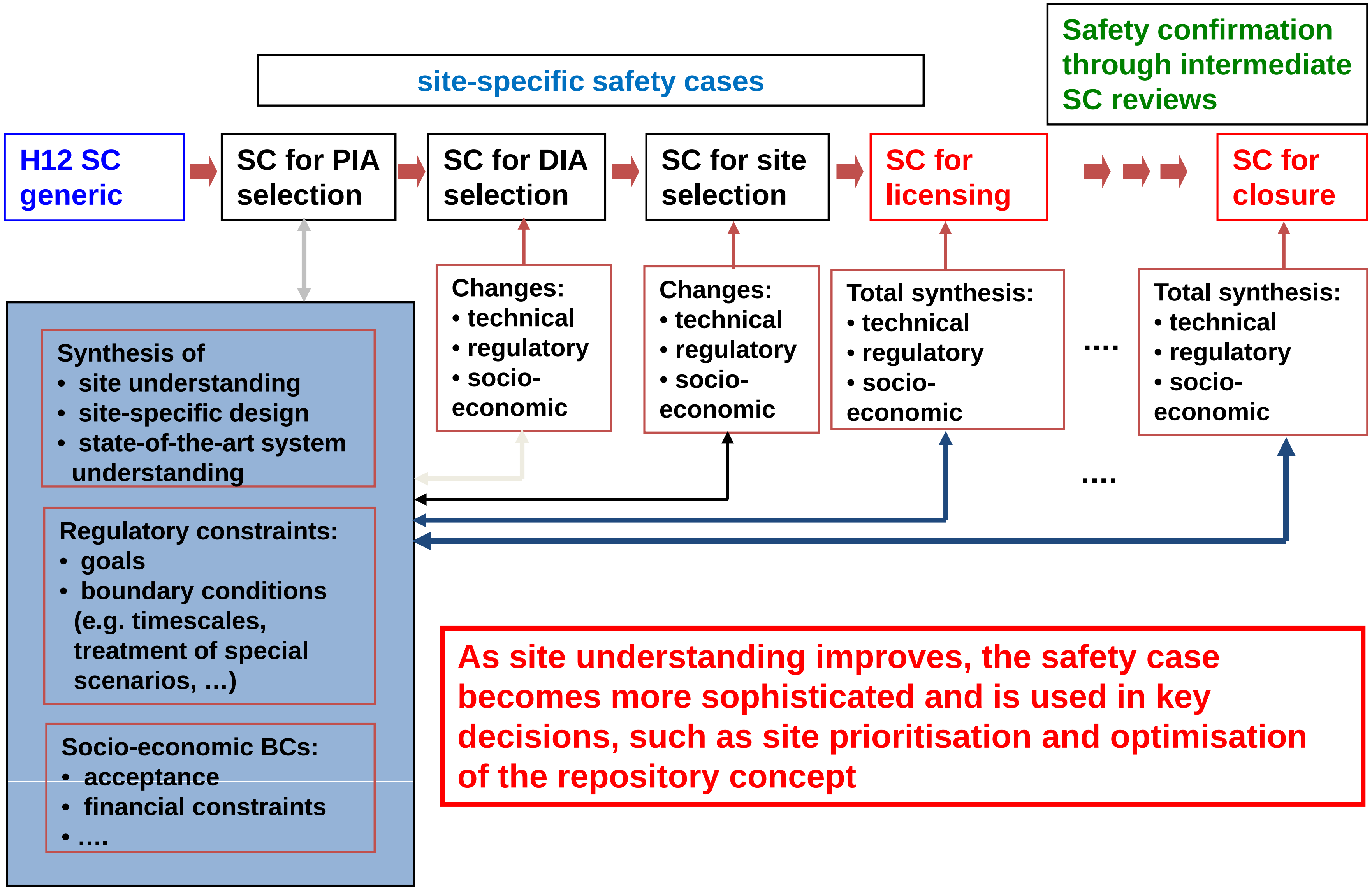


Safety Case – knowledge flows

An alternative representation, that focuses on the structuring and flow of knowledge



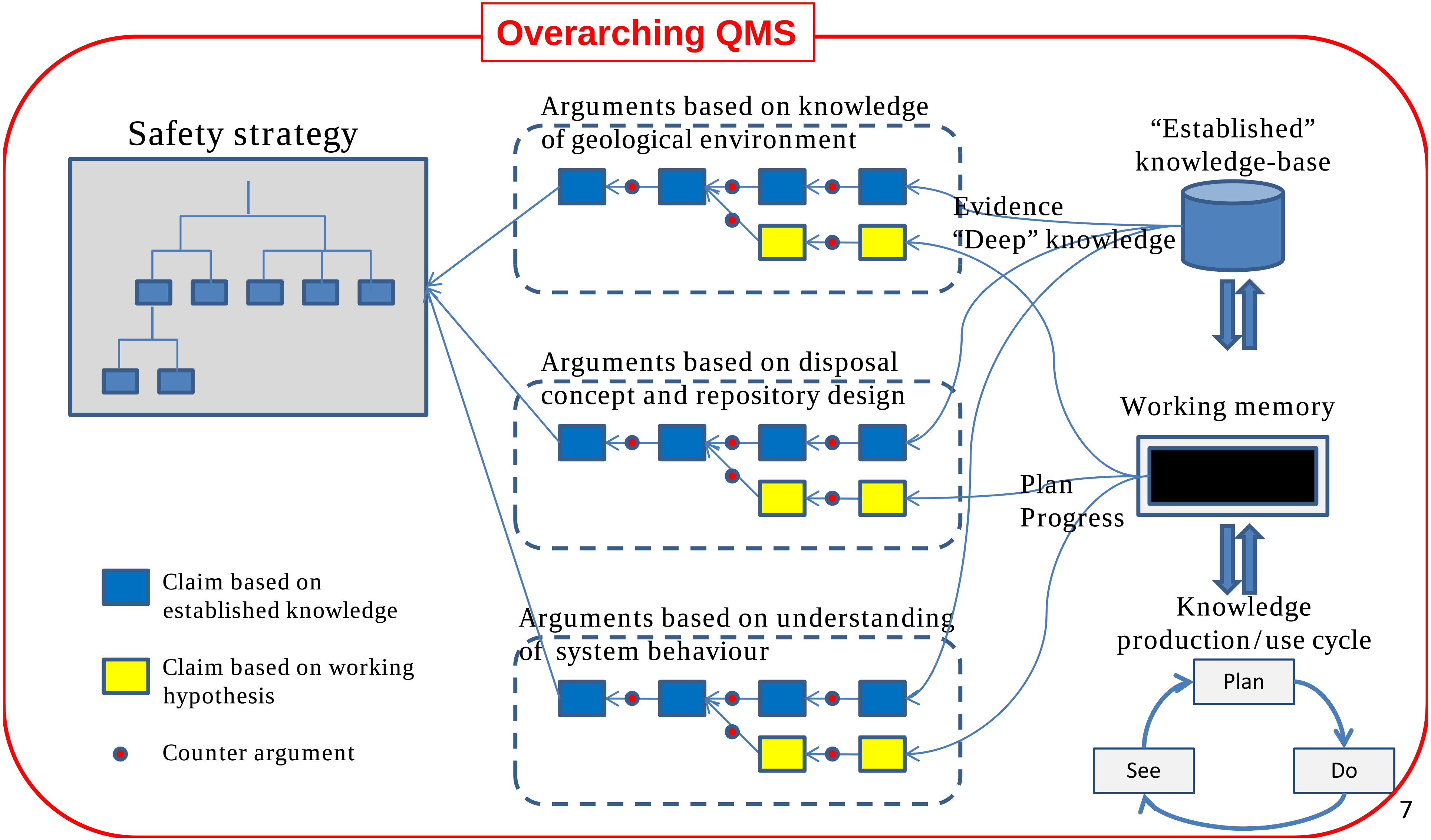
Stepwise evolution of the SC to support site selection decisions



SC as an argumentation network

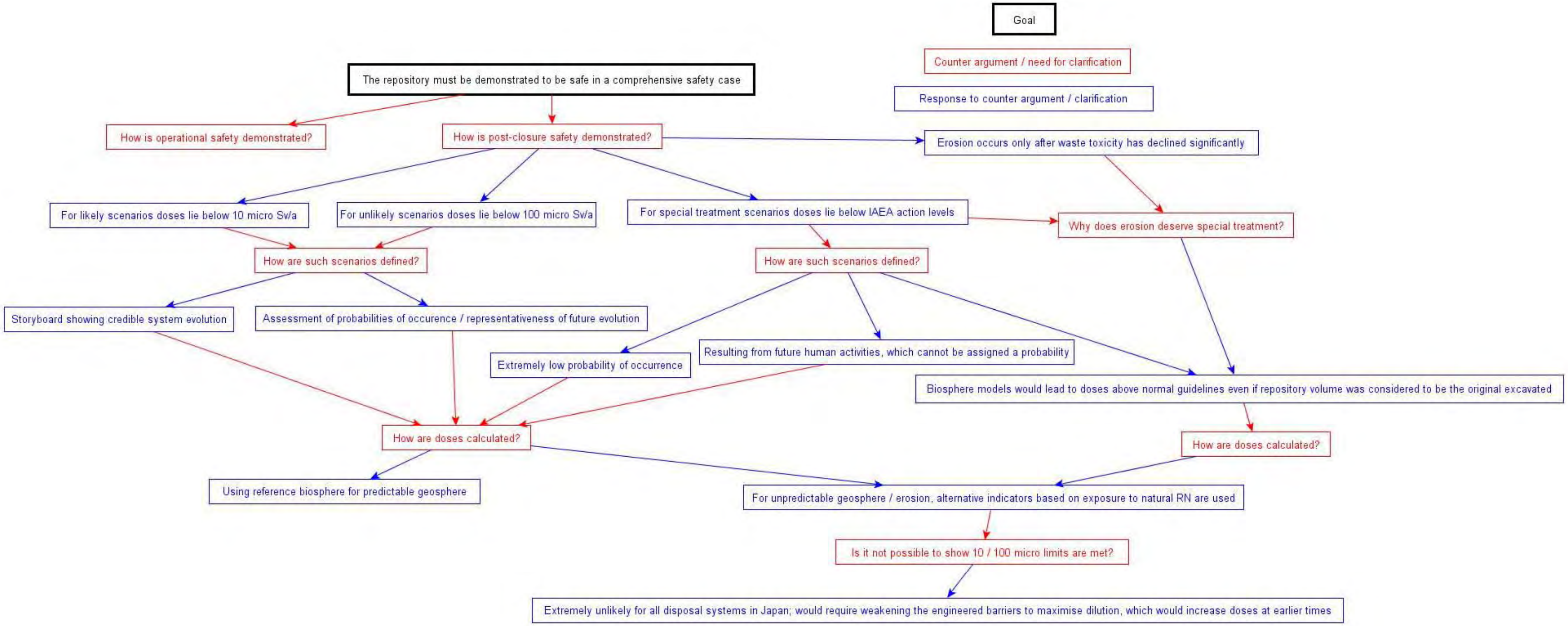
- Evolution of a safety case is an iterative process, reflecting growth of the “knowledge base”
- The dialectic nature of this process can be effectively represented as an argumentation network
- Safety case in each phase should
  - Integrate best available knowledge
  - Contain established knowledge but acknowledge gaps in understanding at early times
  - Keep flexibility in repository concept to counter-balance “surprises” in site characterization or associated R&D
- Key arguments are supported by multiple lines of evidence
- Tight deadlines and limited manpower require utilization of the best and most efficient knowledge management tools available
- Because this safety case may eventually be used to support a license application, knowledge must be quality assured

“Evolving” argumentation model



Argumentation networks

Various software tools facilitate development of argumentation networks that capture the thinking associated with the fundamental claim that “a specific repository is safe”

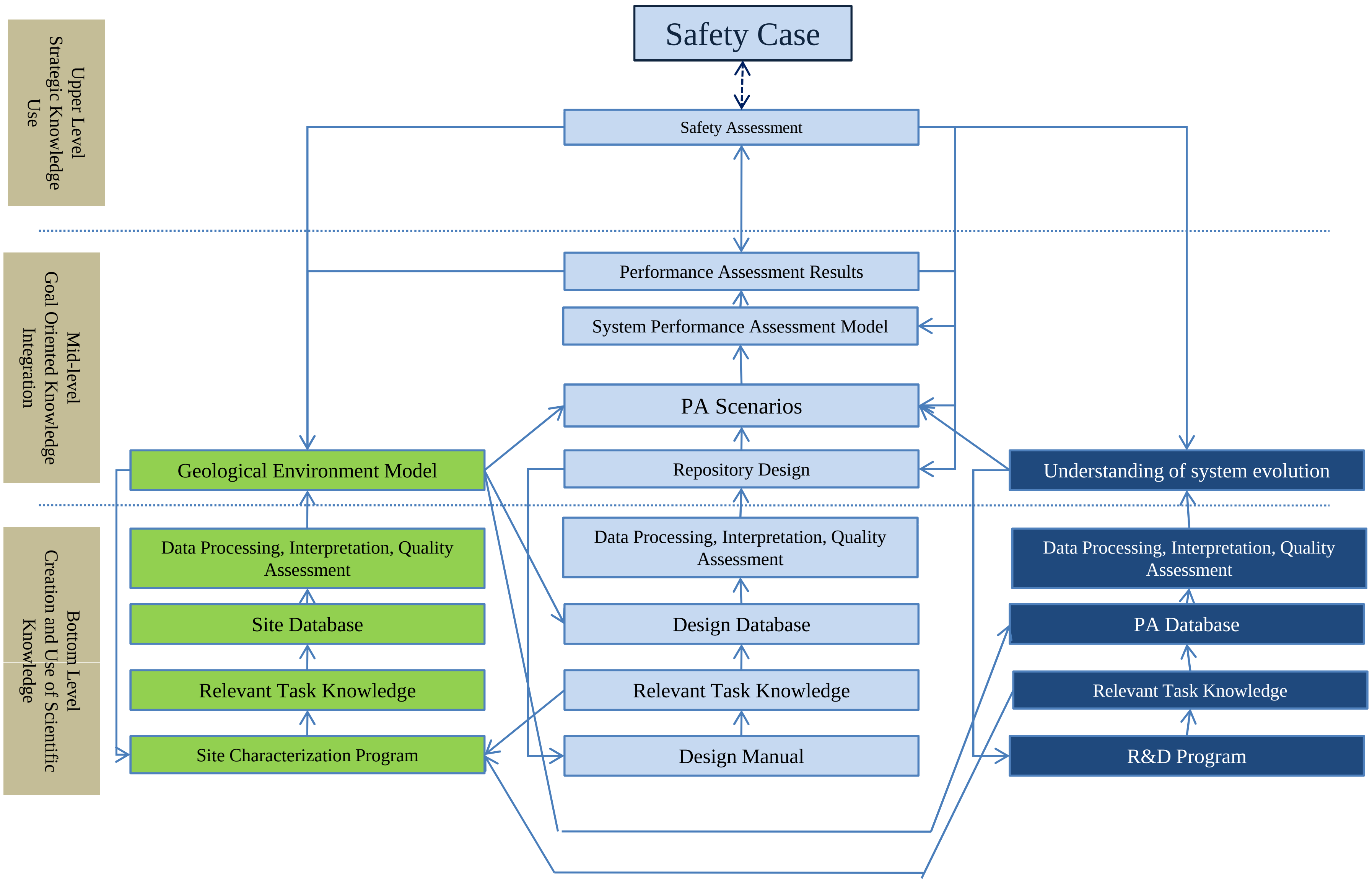


How can a KMS improve the SC?

- Development of hierarchy of requirements and argumentation networks
  - Determine requirements and threats
  - Use argumentation schemes to structure and ensure completeness
- Use of established knowledge
  - Find multiple pieces of evidence to support claims in knowledge base
  - Provide network of "deep" knowledge to help understanding arguments
- Link with R&D program planning
  - Focus on identified safety-critical issues and open questions
  - Real time updates rather than the snapshot of a conventional report
  - Demonstration of readiness for "surprises"
- Communication
  - Interaction
  - Flexible presentation based on needs of particular audiences
  - Use of all modern media

Focusing Knowledge Creation: escaping from bottom-up R&D programs

KMS in knowledge creation and use



Top-down R&D management

- A general problem is that top-level management have no deep understanding of critical technical areas, hence past R&D programmes have a large bottom-up drive from experts who understand the topic involved

- The Safety Case argumentation networks provide an easily understood method of placing even very technical projects in the context of the deliverables required to support the contention that a repository at a specific site is safe – not only helping to set R&D priorities, but also helping Knowledge Producers understand the requirements and constraints on their work

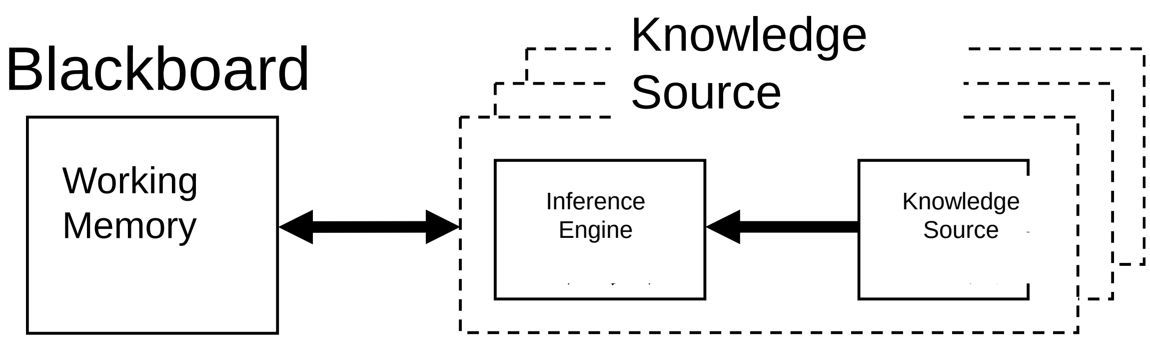
Selecting & applying tools: avoiding re-invention of wheels by customising established KE technology

Key challenges for KMS development

- Problem 1: How can the production and use of various knowledge in diverse fields be systematically managed?
  - Solution ⇒ Blackboard Architecture
- Problem 2: How can all geological environment assessments and surveys be made intelligent?
  - Solution ⇒ Hybrid Knowledge and Information Systems
- Problem 3: How can multiple, diverse expert systems be developed efficiently and have their quality controlled?
  - Solution ⇒ Expert System Development Tools within a strict QMS
- Problem 4: How can the large amount of specialist knowledge of diverse disciplines be efficiently and systematically acquired and organized?
  - Solution ⇒ Formal Knowledge Acquisition Methodology (Problem Solving Method)

Blackboard Architecture

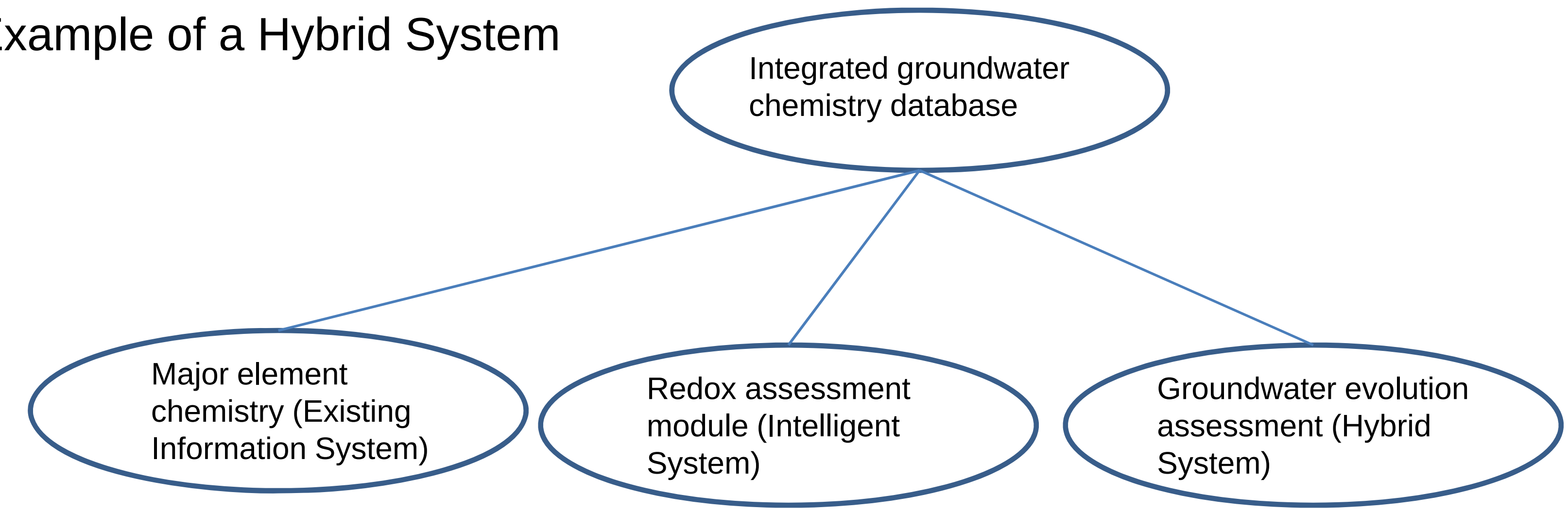
- Problem Solving Model for Scholastic Organizations
- Organizes and displays a shared space where members of a group can view the results of the tasks of individual members and facilitate group cooperation.
- Benefits of using Blackboard Architecture:
  - Provides a problems solving framework based on knowledge integration.
  - Presents a hierarchical structure to express diverse, interrelated knowledge.
  - Aids application of inference engines and other knowledge engineering tools.
  - Offers improvements in development efficiency and maintainability when compared to a single, large-scale knowledge base.



Hybrid Information/Intelligent Systems

- Systems that combine automated knowledge production by intelligent systems and areas in which staff use existing information systems to process information.
  - Existing information systems fulfill specific pre-defined functions on shared data groups stored in a certain location (a database) on the basis of procedural knowledge.
  - Intelligent systems are designed to produce new information using declared knowledge and some kind of inference mechanism.

Example of a Hybrid System



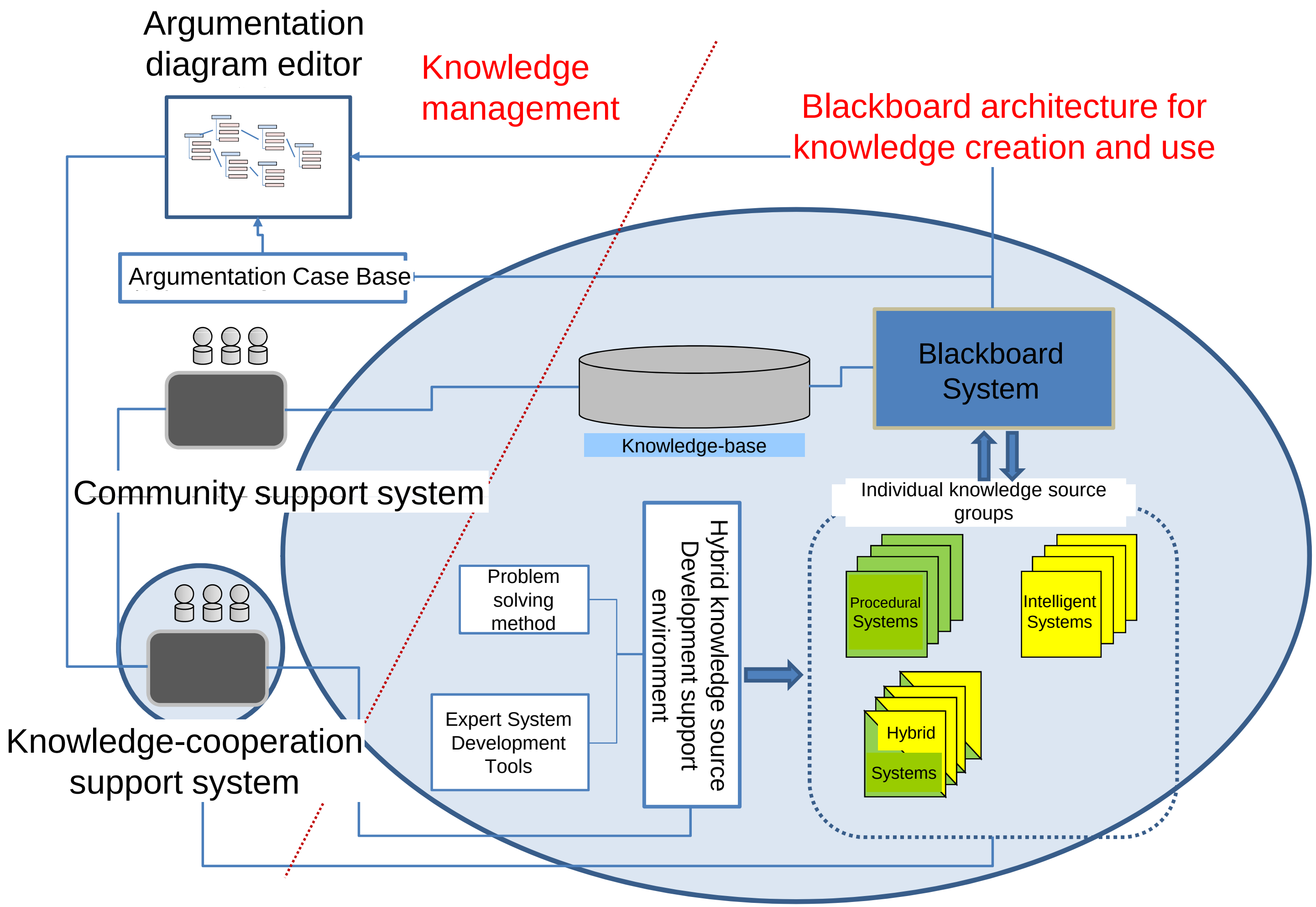
Expert system development tools

- Types of Tools
  - Programming Languages (Procedural/Declarative)
    - Flexibility is highest.
    - Development time is longest.
  - Expert System Shells (Ready-made ES templates without a KB)
    - Have highest flexibility
    - Development time is shorter
  - Expert System Development Environments
    - Flexibility is low: in particular unsuited to non-routine development such as research development
    - Development time is even shorter
- Selection Criteria
  - **When choosing between these options you should use a shell where you can, an environment when you should and a language only if you must**.

Use of formal Problem Solving Methods

- This method specifies the necessary knowledge and necessary task sequence for problem solving before constructing an expert system.
- The inference process used by experts to solve problems is called task knowledge. Because it is totally different than the domain knowledge related to the subject, the collection of related knowledge is modeled separately from these processes.
- By modeling expert related problem solving process task knowledge of the general (symbolic) tasks involved in the design, diagnosis, and planning necessary to solve problems, a generic problem solving method not dependent on the subject domain can be constructed.
- The standard PSM library is KADS (Knowledge Acquisition Design System) or its successor CommonKADS. The KADS approach includes the following three knowledge acquisition processes.
  - Elicitation
  - Analysis: Interpreting elicited knowledge
  - Formalization: Expressing the knowledge in a way that can be used by a computer

Structure of the JAEA KMS



Argumentation networks: structuring safety case components in a natural manner to aid assessment of completeness

Aims

Illustration of test application of yEd software for constructing argumentation networks (can be downloaded free from http://www.yworks.com/en/products_yed_about.html)

Linked to the argumentation classes as listed in the next slide. In the networks, all arguments are assigned to one of these classes although, in practice, this assignment may be somewhat subjective in particular cases. Counter-arguments are highlighted, as a drive to expand the knowledge supporting the initial claims. It must be emphasised that these examples are illustrative only and need to be carefully reviewed and expanded before they can be considered reasonably complete.

Argument classes and numbering used

A1:Argumentation based on fundamental law of science
A2:Argumentation based on accepted principles
A3:Exclusion based on defined criteria

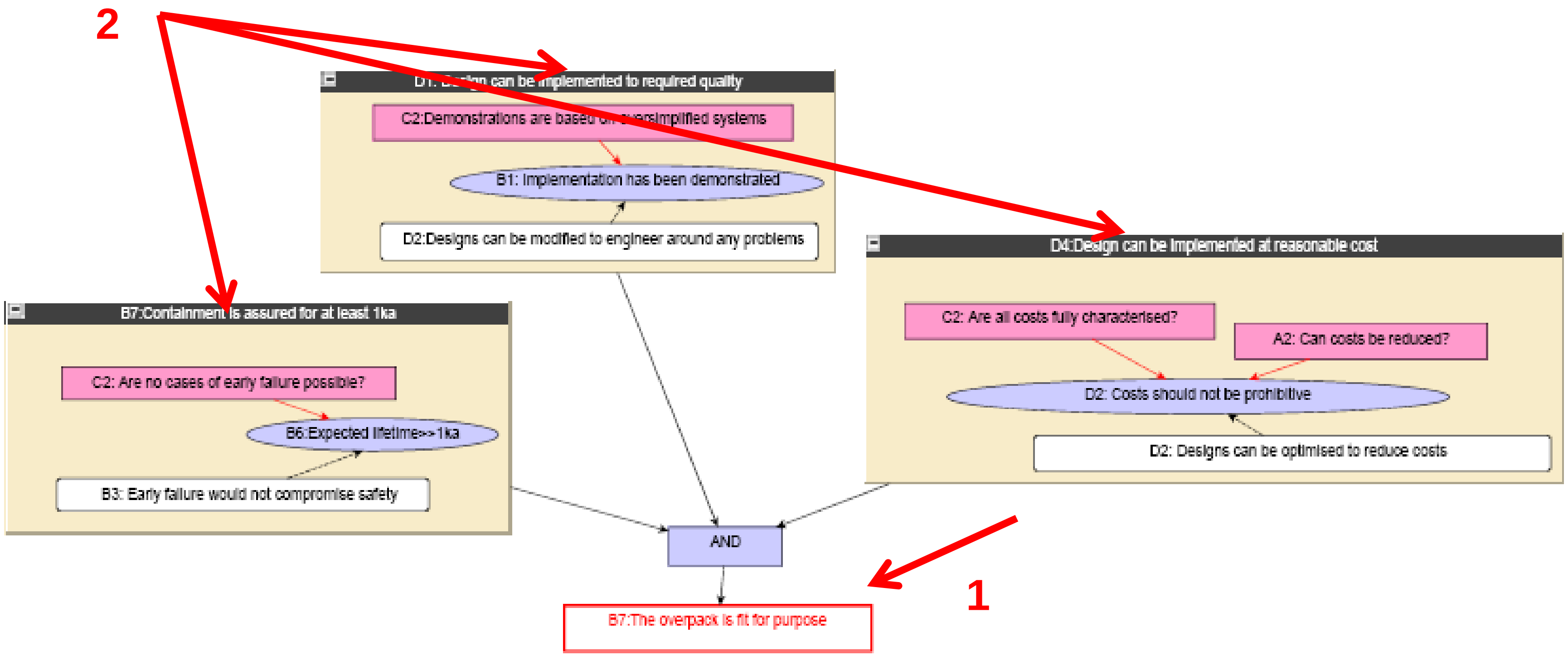
B1:Argumentation based on experimental data
B2:Quantitative prediction based on fundamental models
B3:Quantitative prediction based on empirical models
B4:Argumentation based on analogy
B5:Argumentation based on interpolation
B6:Argumentation based on extrapolation
B7: Argumentation based on expert judgment

C1:Argumentation of conservatism
C2:Argumentation of completeness
C3:Argumentation of robustness

D1:Argumentation based on common understanding
D2:Argumentation based on precedence
D3:Argumentation based on ethics
D4:Argumentation based on economics
D5:Argumentation based on public acceptance

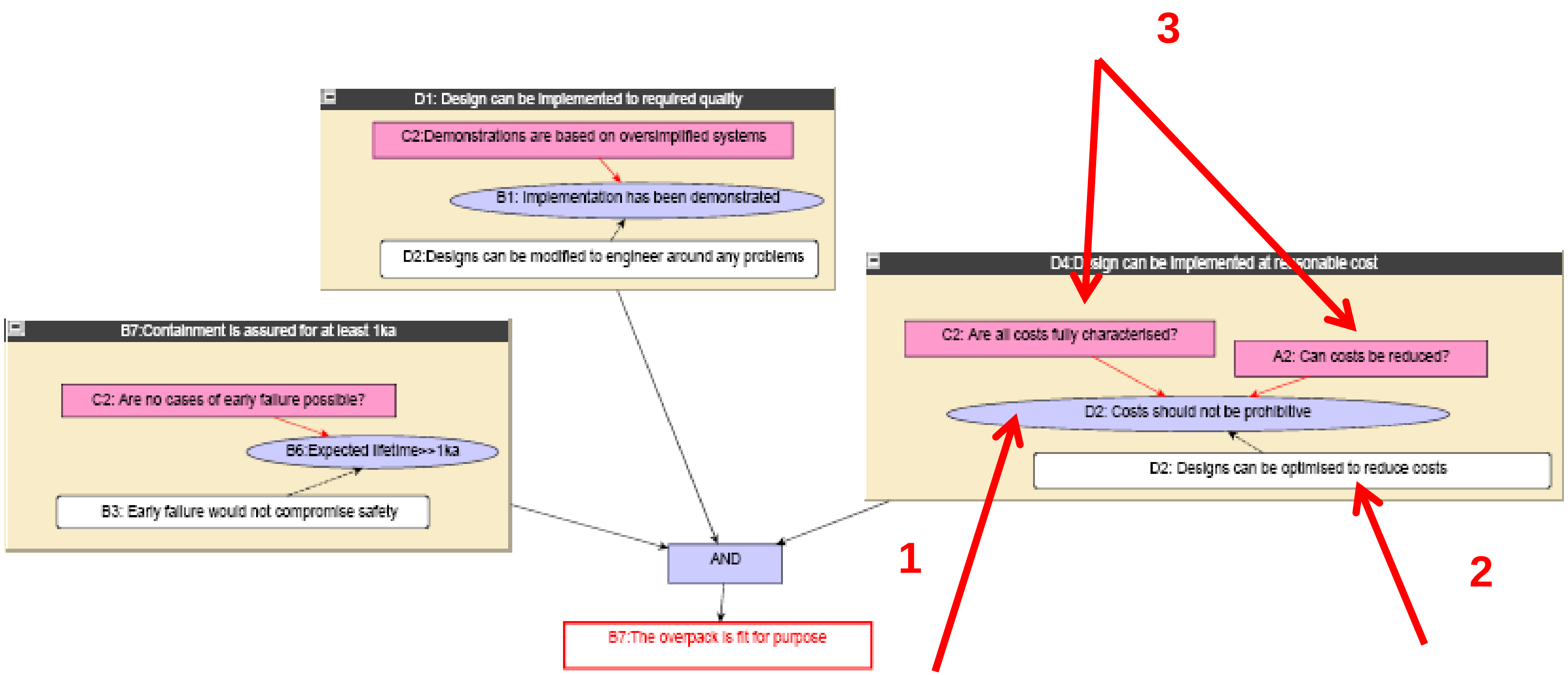
Sub-system example: Overpack

Starting point – Initial claim (1)
"The overpack is fit for purpose" – argument class B7
This is supported by arguments for safety role, practicality and economic feasibility (2)



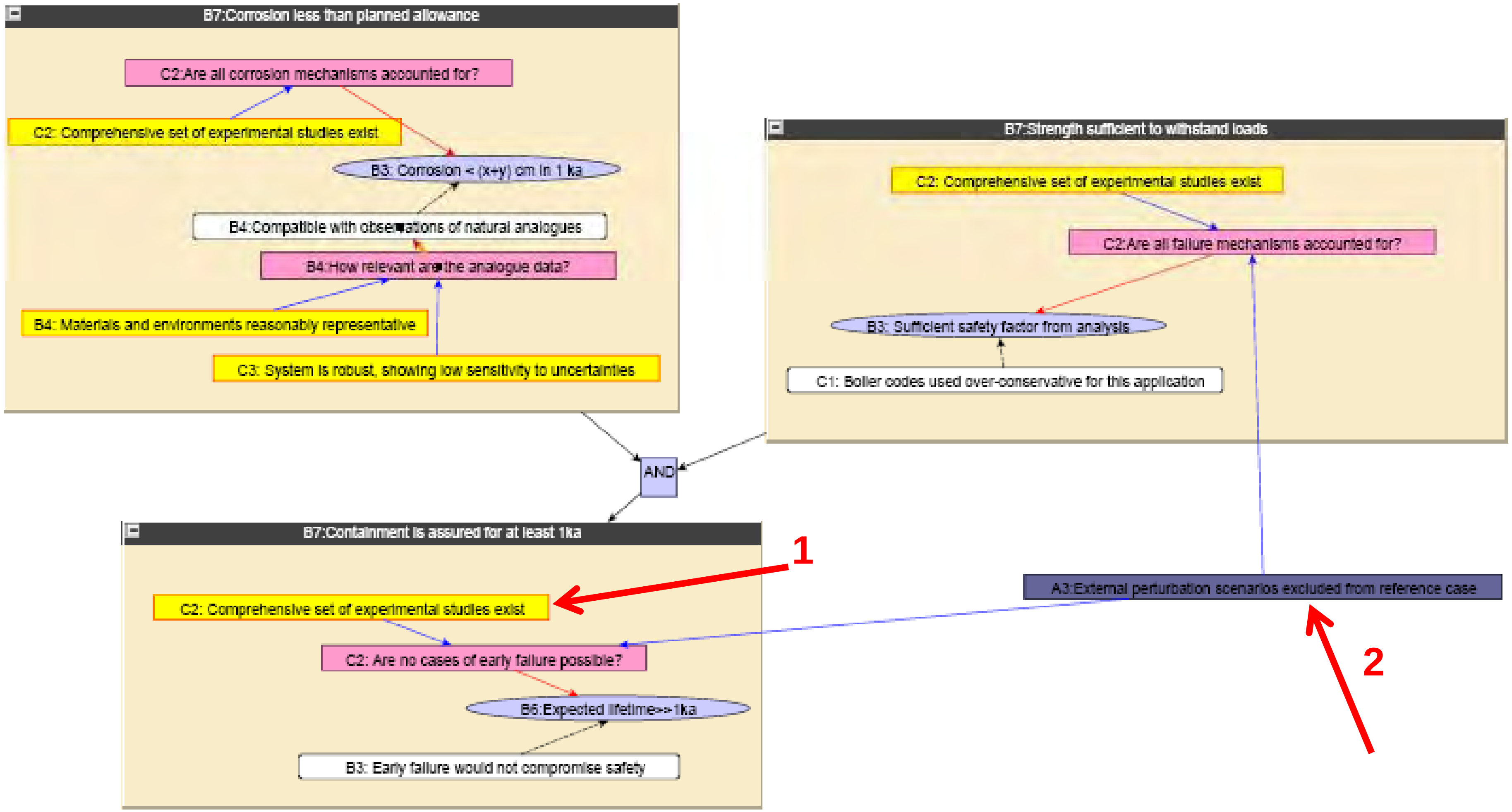
Sub-system example: Overpack

Each of the supporting arguments includes a more specific claim (1) which is shown in the ellipse.
This is supported by arguments or information that is summarised in the white rectangle (2)
Counter-arguments to the claim are given in pink boxes (3)



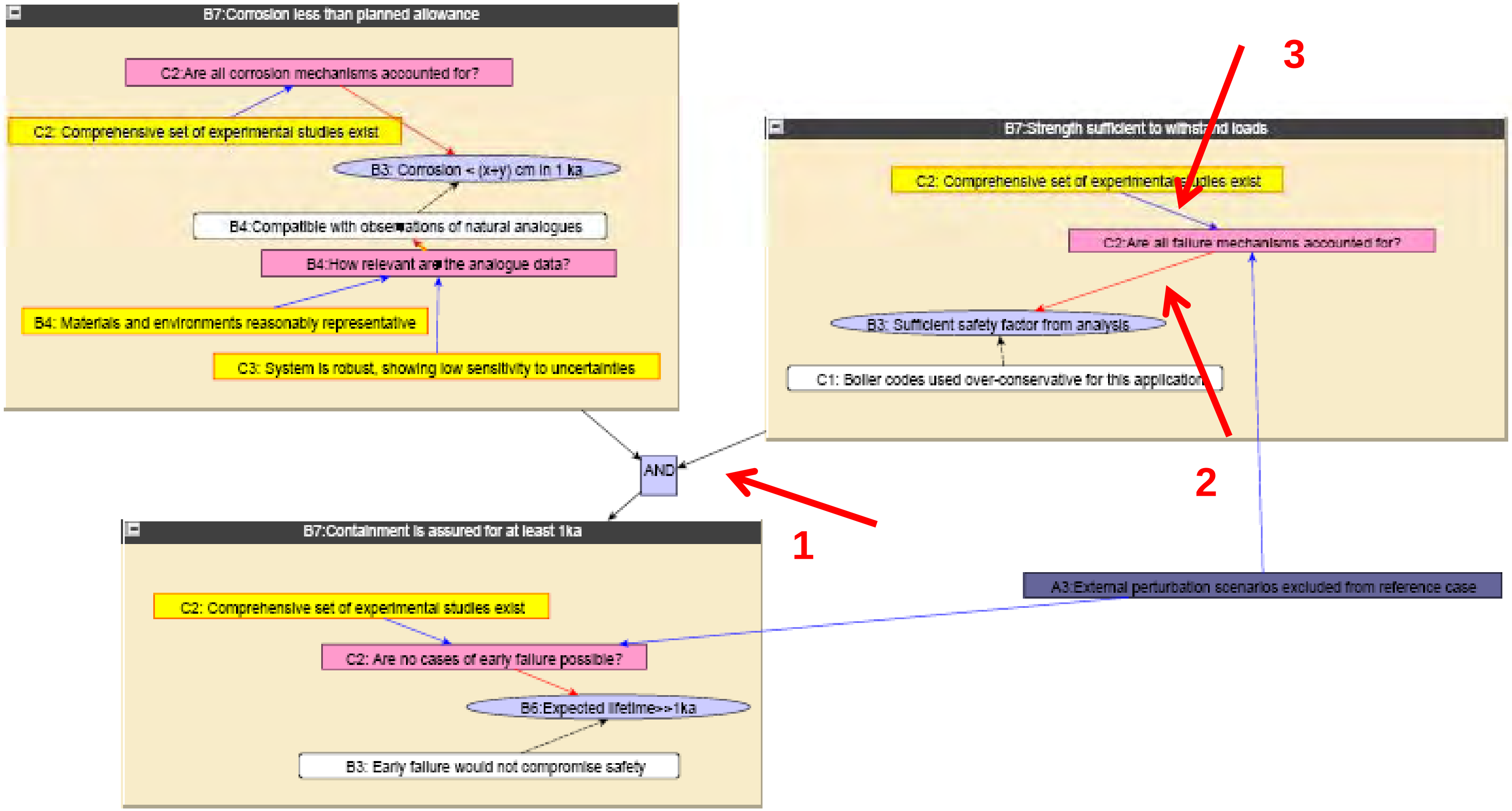
Sub-system example: Overpack

Each counter-argument requires a response – which could be direct, indicated by a yellow box (1), or may be a constraint set on the level of treatment that is being carried out (blue box)(2)

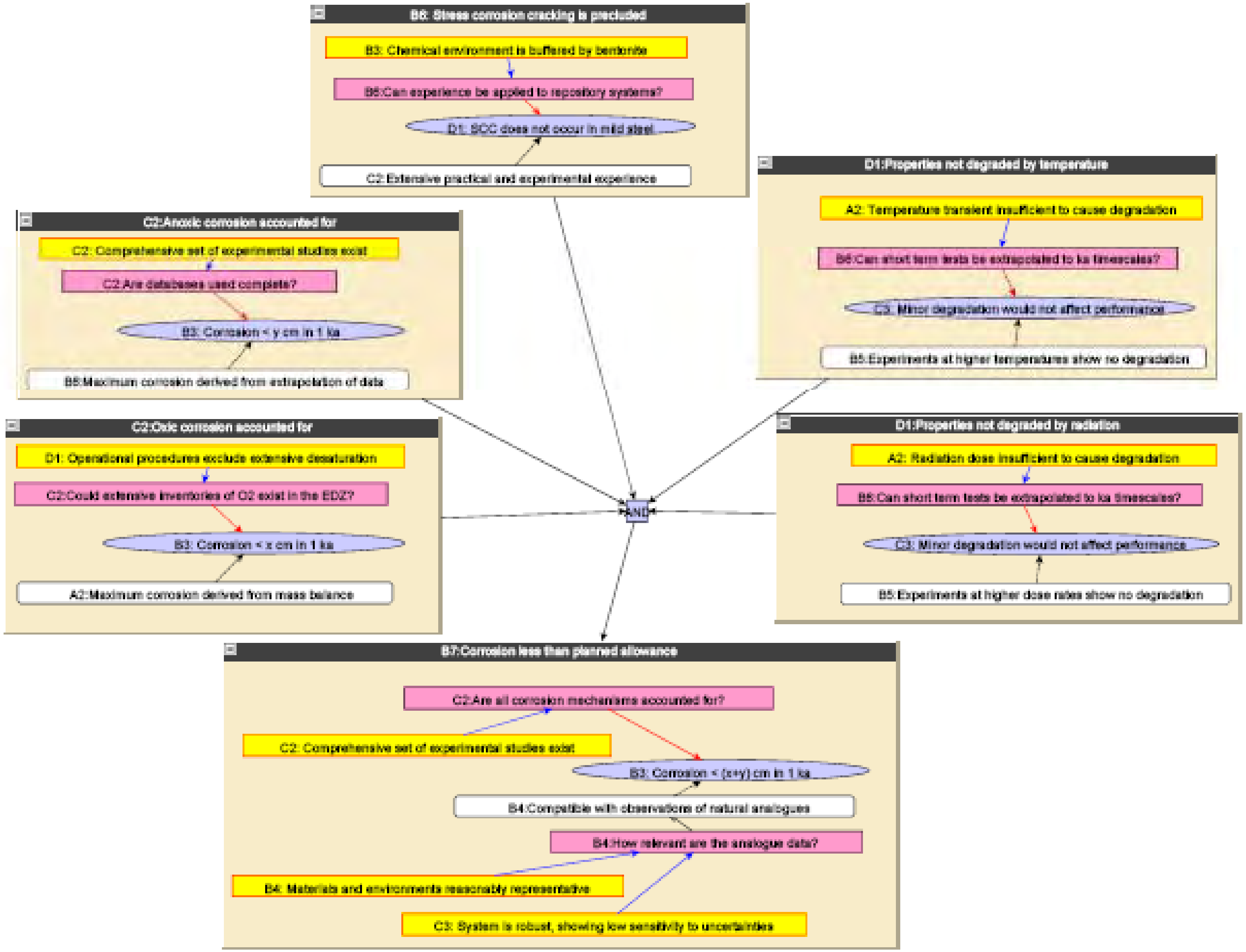


Sub-system example: Overpack

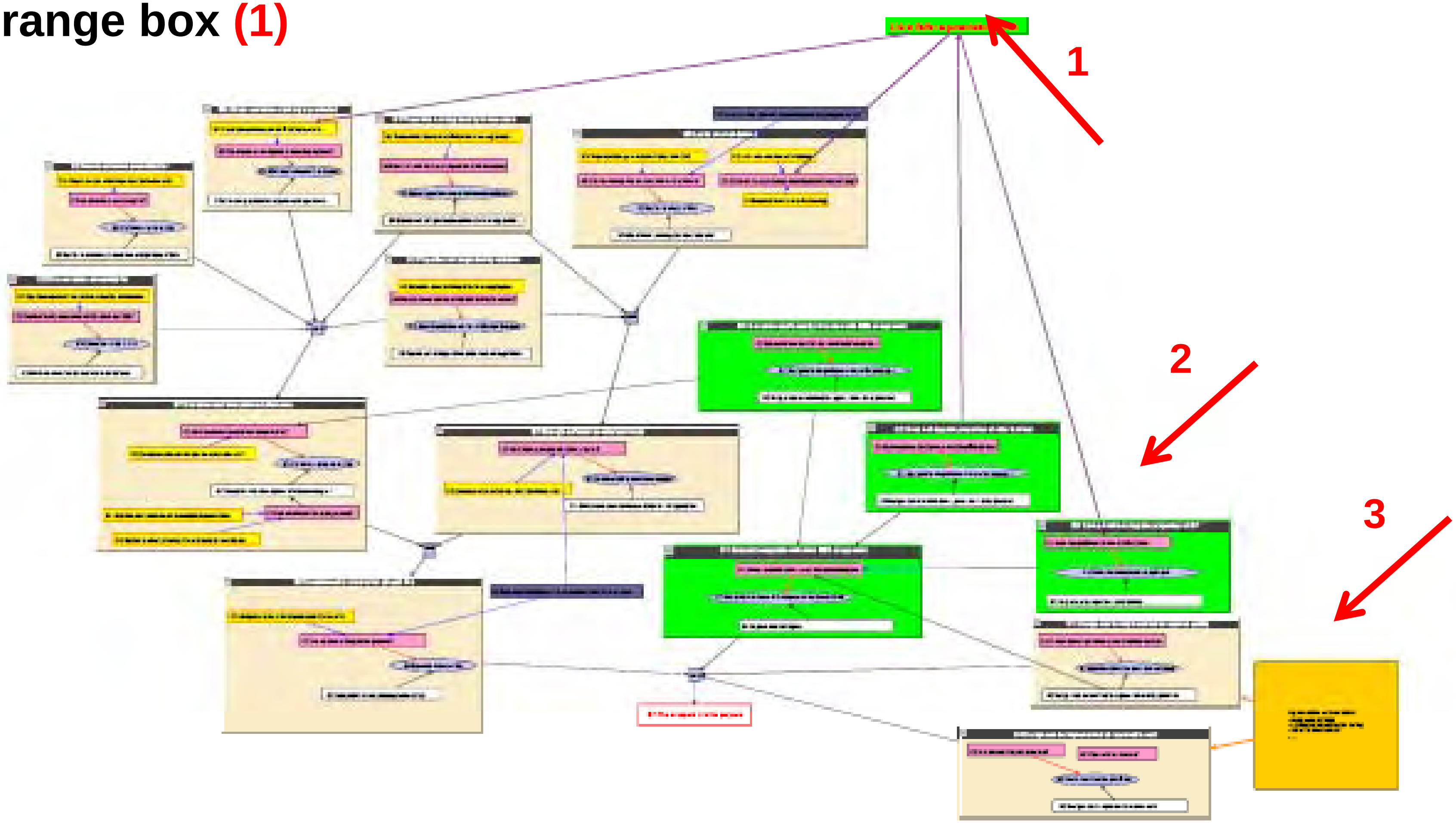
Top level claims may be supported by further arguments, the flow of information being indicated by black arrows (1); NB links of counter-arguments are given as red arrows (2) and responses to these as blue arrows (3)



…this is then expanded further to develop the network

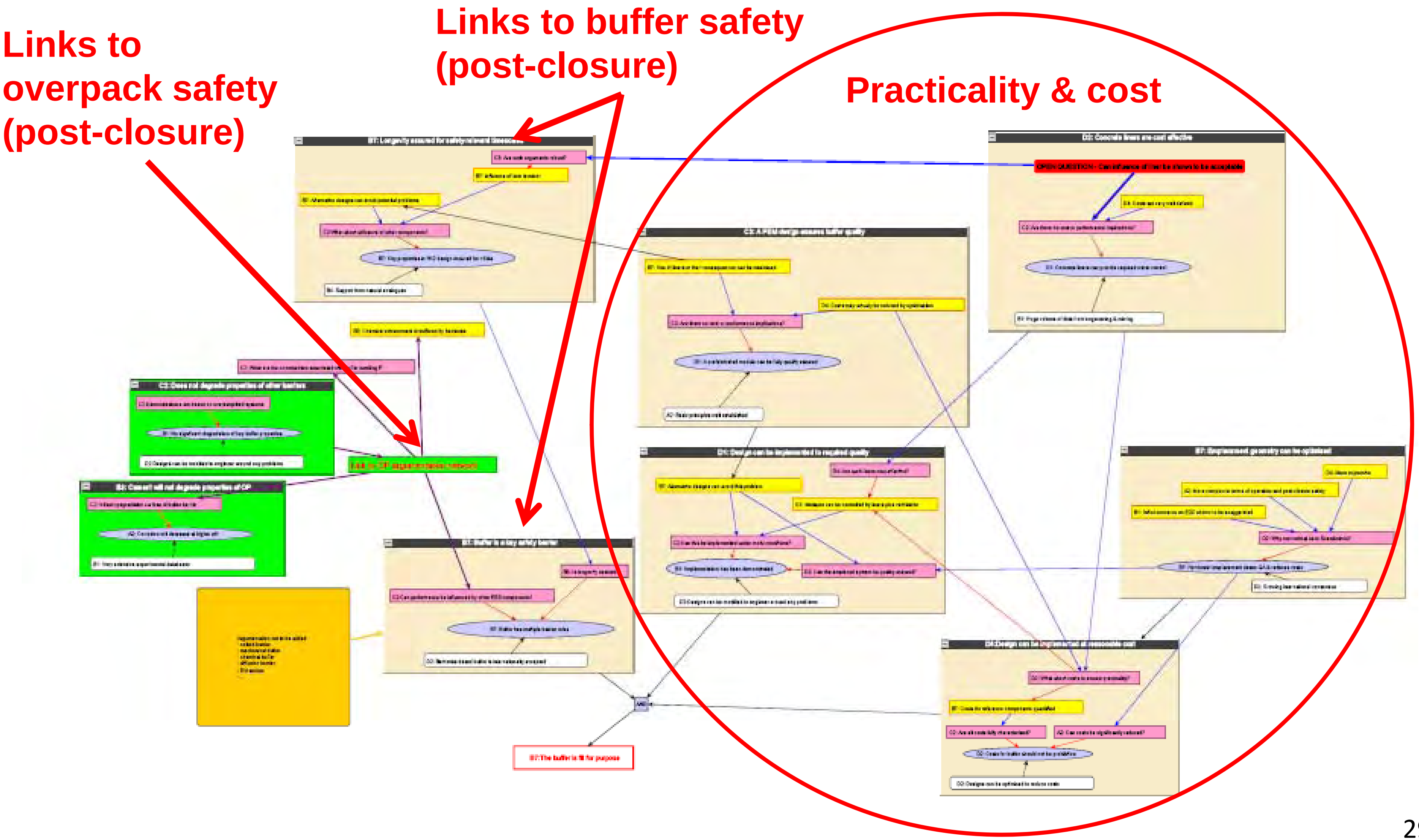


…as the network becomes more detailed, inevitable links to other sub-systems are required, e.g. for the overpack, a set of links to the buffer sub-system (1); the figure also illustrates how additional input from an expert can be incorporated and highlighted by green boxes (3) and incomplete areas where examples of the arguments to be included later are indicated in the orange box (1)

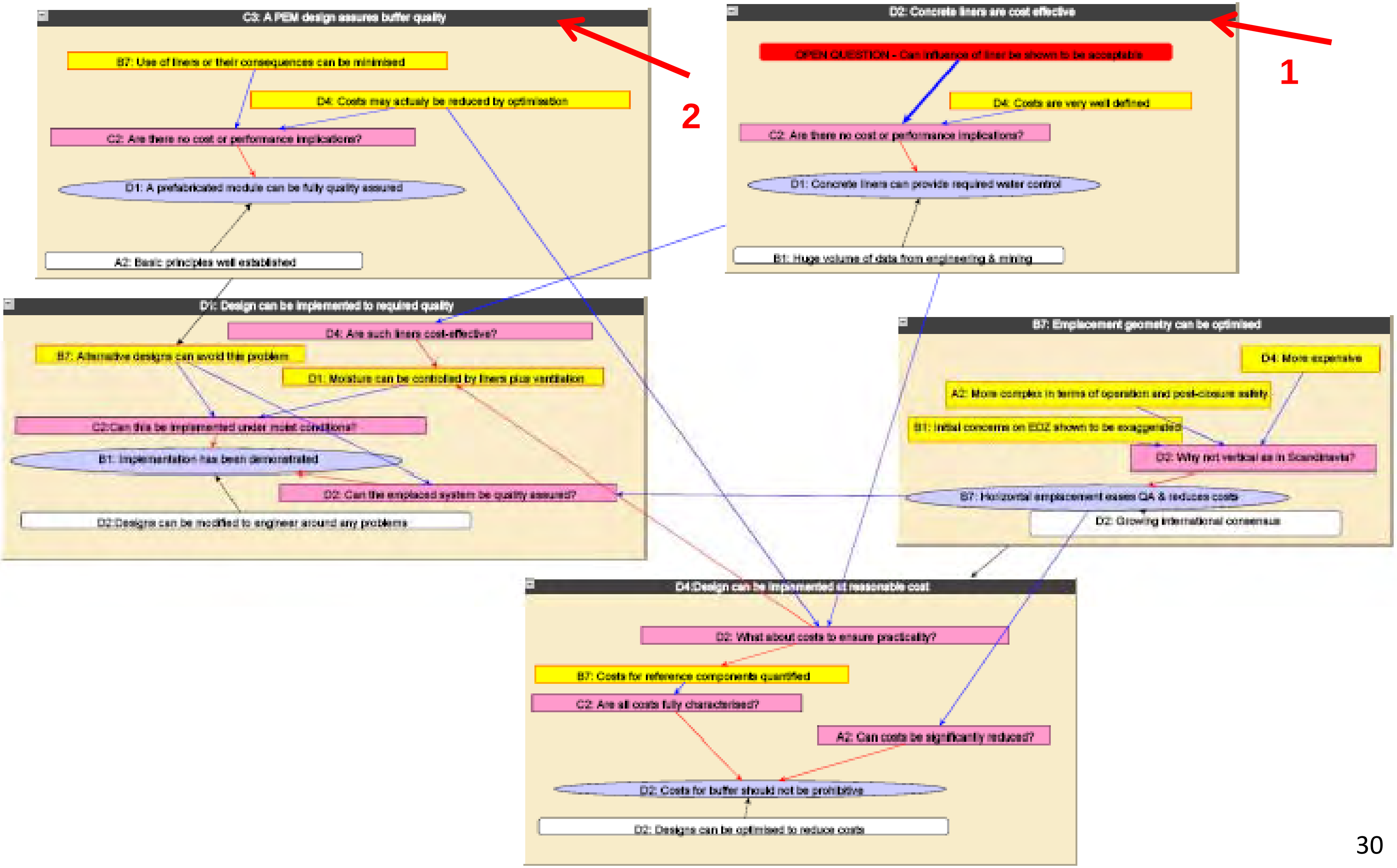


Sub-system example: Buffer

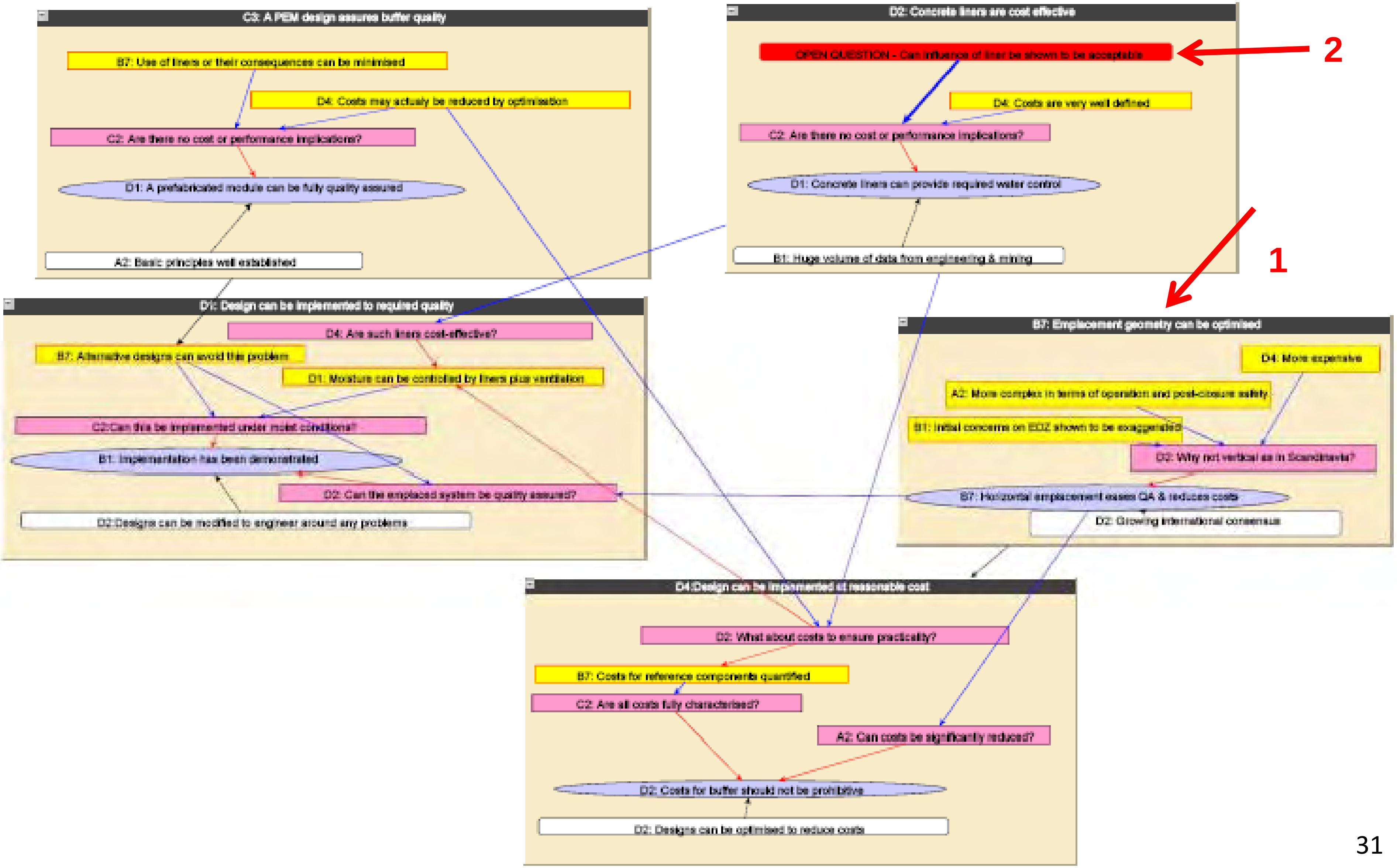
Arguments based on practical and cost constraints on the buffer are indicated: the linkages are clearly more complex than for the overpack



...in detail, concerns about practicality of handling buffer under wet conditions and QA lead to consideration of use of liners (1) or alternative designs based on a PEM (2)



...cost and practicality also lead to a focus on horizontal emplacement options(1); the concrete liner option leads to an open question in the red box (2) – this is a key issue that should be a focus for future clarification



Synthesis

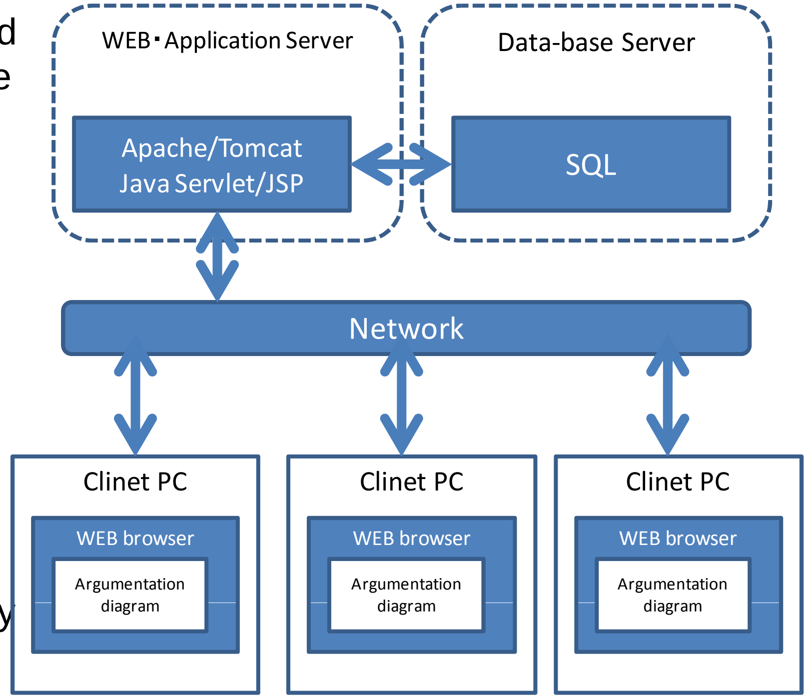
The examples indicate that the knowledge that supports a repository implementation programme can be very effectively organised using such an approach

In many ways this is equivalent to identifying and linking key FEPs that need to be considered when building a safety case (NB this is wider than conventional PA scenario analysis as practicality and socioeconomic issues are directly included)

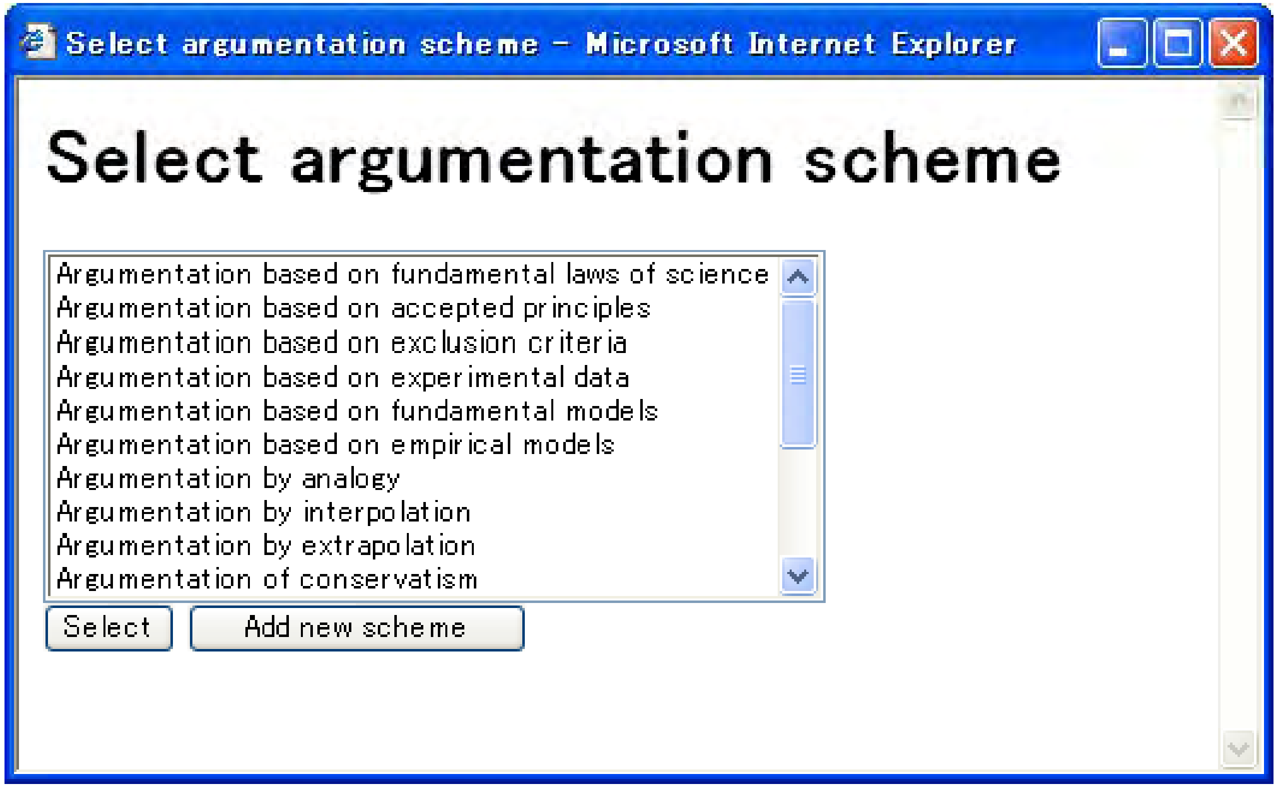
Further tools have been examined to take such an approach further – as illustrated in the ISIS case study

KNetwork
Argumentation support system on web

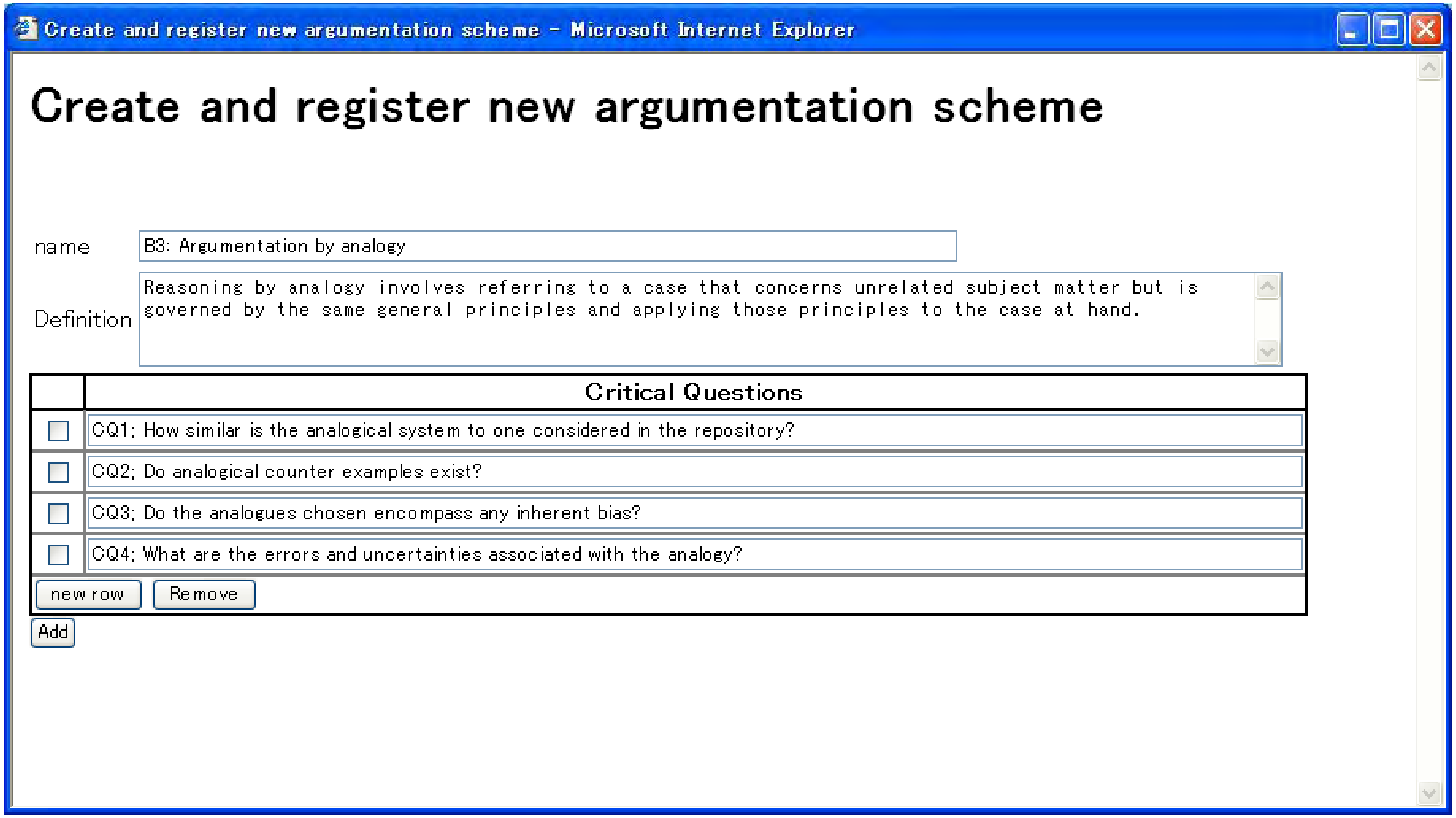
- Support user to construct argumentation by GUI
  - Create and edit argumentation diagrams
  - Search argumentation scheme from menu bar and guide user to define new argument using template
  - Create knowledge note on evidence referred to in an argument
  - Search existing arguments from argument case-base
  - Search possible counter arguments by using knowledge network
- Provide collaborative working environment on Web
  - Link with a groupware to support communication and discussion among members of the community
  - Access to a knowledge base containing information on evidence, case-base, knowledge network etc.
  - Log recording changes to a diagram made by members



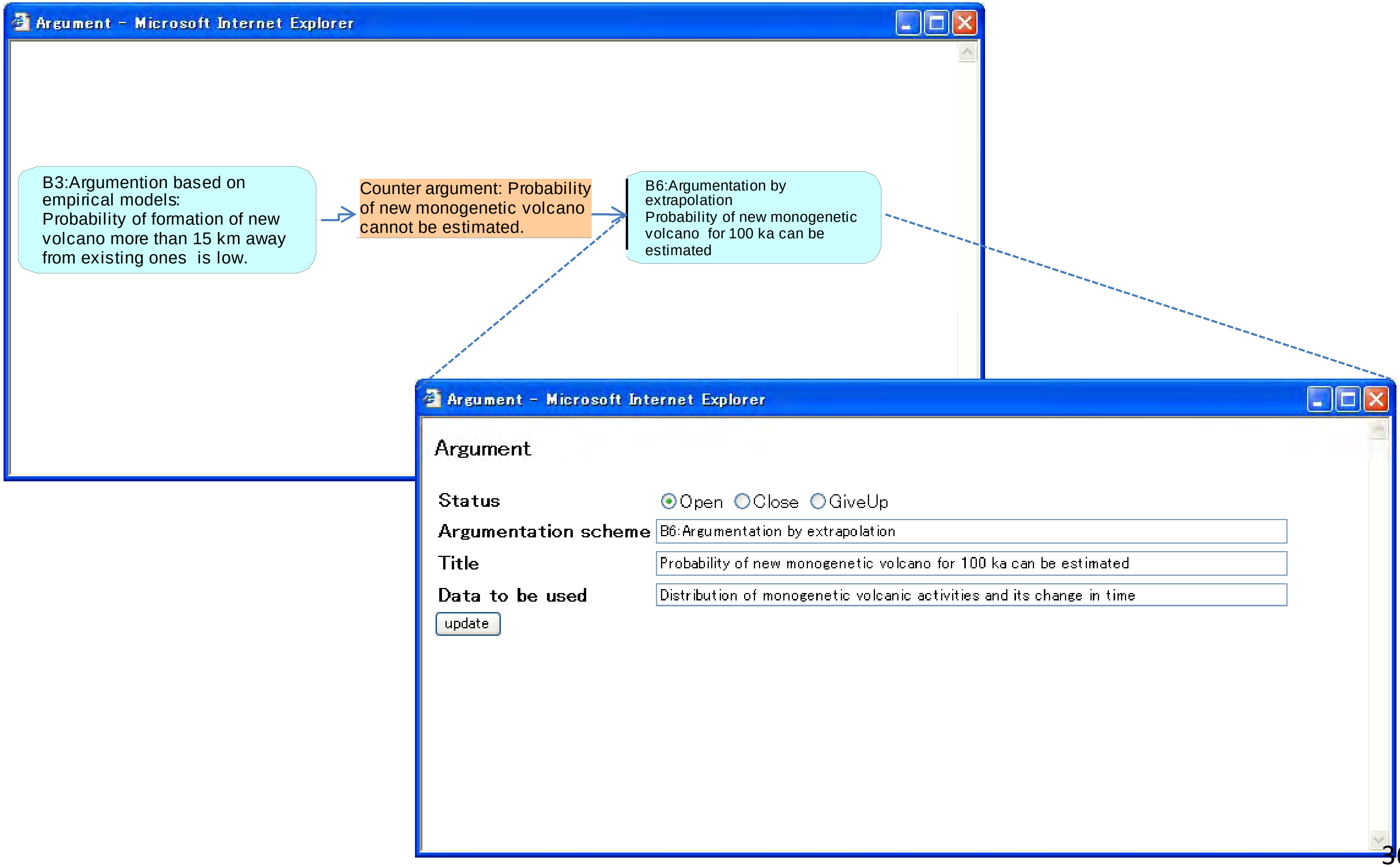
Selection of argumentation scheme



Create and register new argumentation scheme



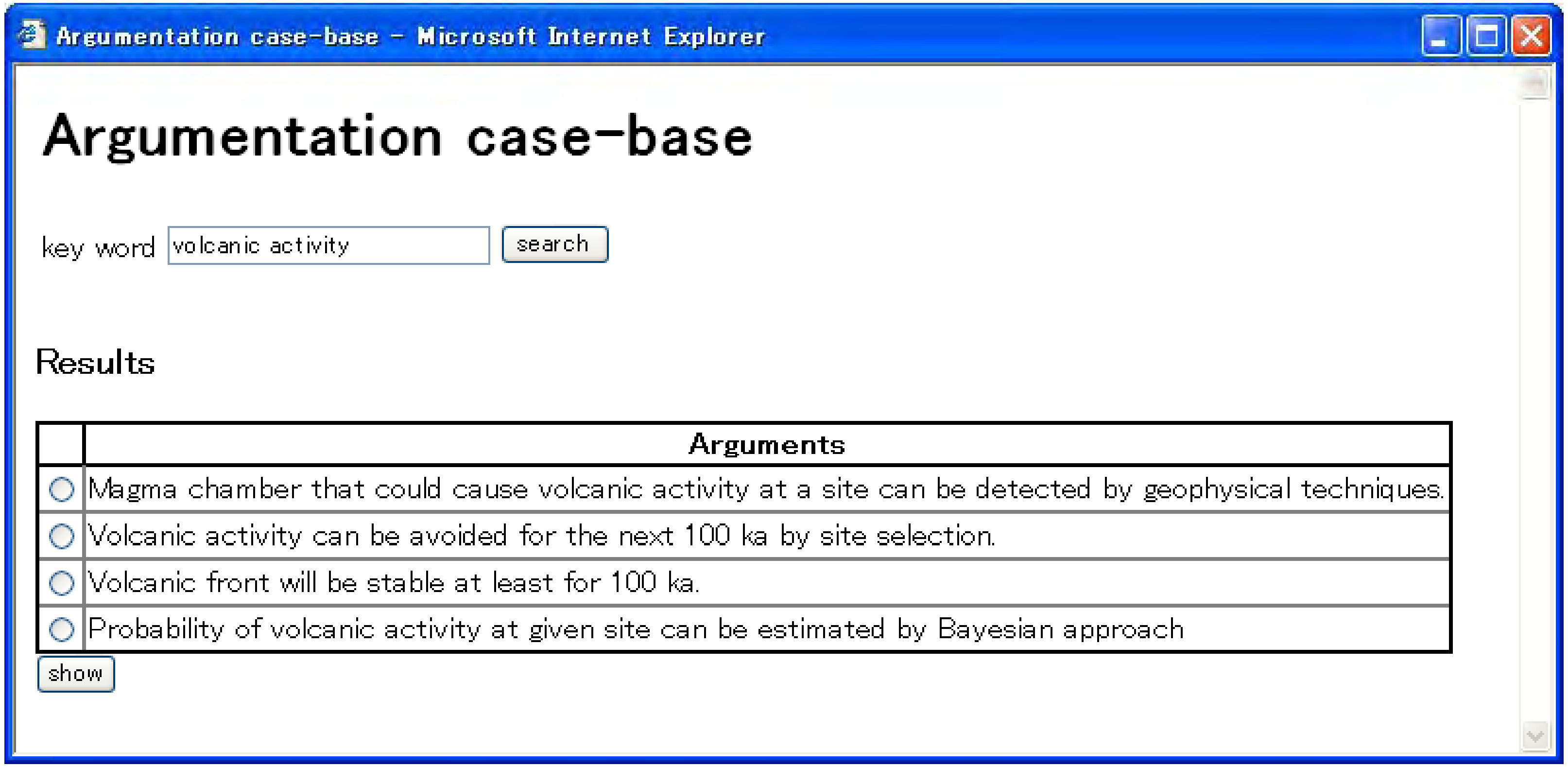
Defining attributes of new argument



Record of knowledge use in argumentation using "Knowledge note"

- Describe and record knowledge and information associated with individual arguments
  - Evidence supporting arguments in argumentation model with note on its limitation, uncertainties, etc.
  - Knowledge relating to mapping between argumentation model and knowledge-base
  - Changes in arguments and/or use of evidence
- Provide indices for argumentation case-base for future re-use
  - Keywords appearing in argument and evidence
  - Summary of related knowledge and information
  - Argumentation scheme selected
  - Critical questions that were activated to form further counter-arguments
  - Author
  - Time of creation and use

Key word search in argumentation case-base



QM: application where, when and to the extent needed

Quality management

- Can be prioritised by the safety case – level of quality required is related to the contribution to the safety case
- Implementation ongoing at several levels:
  - Technical level – QA workshops and implementation programme for URL field work
  - Integrated completely into H22 planning (already well established for H12)
  - Testing within geosynthesis test cases
- Recognised to be a challenge to implement within the KMS and will be the focus of a workshop planned for early 2009

Implementation plan:
stepwise introduction with priority for key areas that have greatest problems managing data flows – e.g. geosynthesis

KMS implementation

Needs to have a responsible group at an appropriate level:

- Top management - concerned with top-level requirements (politics, legislation, budget,...)
- **KM group - responsible for management & guardianship of Knowledge**
- Operational staff - more concerned with creation and use of Knowledge

Commitment at all levels is a fundamental requirement

Resources are needed to rapidly develop user-friendly support tools (encourages active support)

Cost / benefit may be optimised by collaboration with international partners

KM staff require to develop experience in knowledge integration as quickly as possible, e.g. via integrated PA, geosynthesis, etc.

Implementation plan

Concentrate on key problem areas – e.g. tailoring designs to the specific conditions found at volunteer sites and optimising these for specific boundary conditions at such locations

Aim to maximise synergy between the specific work areas targeted (transfer of experience, technology, etc.)

Work to the nominal (optimistic) time plan for repository siting to ensure that tools and knowledge bases are available when required

Balance short term need to meet deadlines with long-term requirements for multi-decade databases and experienced manpower

The challenges of advanced design

- The design is the most visible aspect of repository planning and hence a focus for public concern. A flexible design process supported by advanced PA tools allows optimisation that will not only improve operational safety and practicality, but may also reduce costs without degradation of post-closure safety margins

- Provides basis for major decisions that may determine success or failure of a particular program

- Each site provides new challenges and surprises and hence real-time knowledge management is critical

A look to the future: the KMS as a resource for implementers, regulators and other stakeholders

Outline of future developments (1)

Although the principles of the KMS are reasonably well established, the critical challenge is to develop and demonstrate practical applications of the toolkit that clearly show the benefits involved. For advanced designs and PA, stepwise implementation is focusing initially on:

- Development of extended and complete repository concepts
- Identification of critical factors associated with the use of secondary barriers (e.g. concrete – bentonite interaction)
- Determination of prioritised requirements for the next generation of PA models

Outline of future developments (2)

Other test cases associated with geosynthesis are initially running in parallel, but these will be coupled as soon as practically possible. Clear interfaces arise for all 3 sub-topics as interactions with geosynthesis teams will be needed to define:

- Geological boundary conditions for design and an assessment of how associated uncertainties would vary with development of the characterisation programme
- Interactions of the geosphere with the EBS (e.g. concrete-host rock reactions)
- Requirements for realistic modelling of the geological barrier role

Application of KMS Technology Toward Advanced PA: Concept and Approach

Workshop to Review the Progress of the Development of a Knowledge Management System (KMS) and Its Application toward Advanced Performance Assessment (PA)

13-14 November, 2008
Tokyo

Kaname Miyahara

Contents

- Challenges
- Establishing boundary conditions – future needs
- Concepts for the next generation of designs
- Requirements for the next generation of PA
- Plan for development and implementation

This study was carried out by JAEA under the contract with the Natural Resources and Energy Agency, Ministry of Economy, the Trade and Industry.

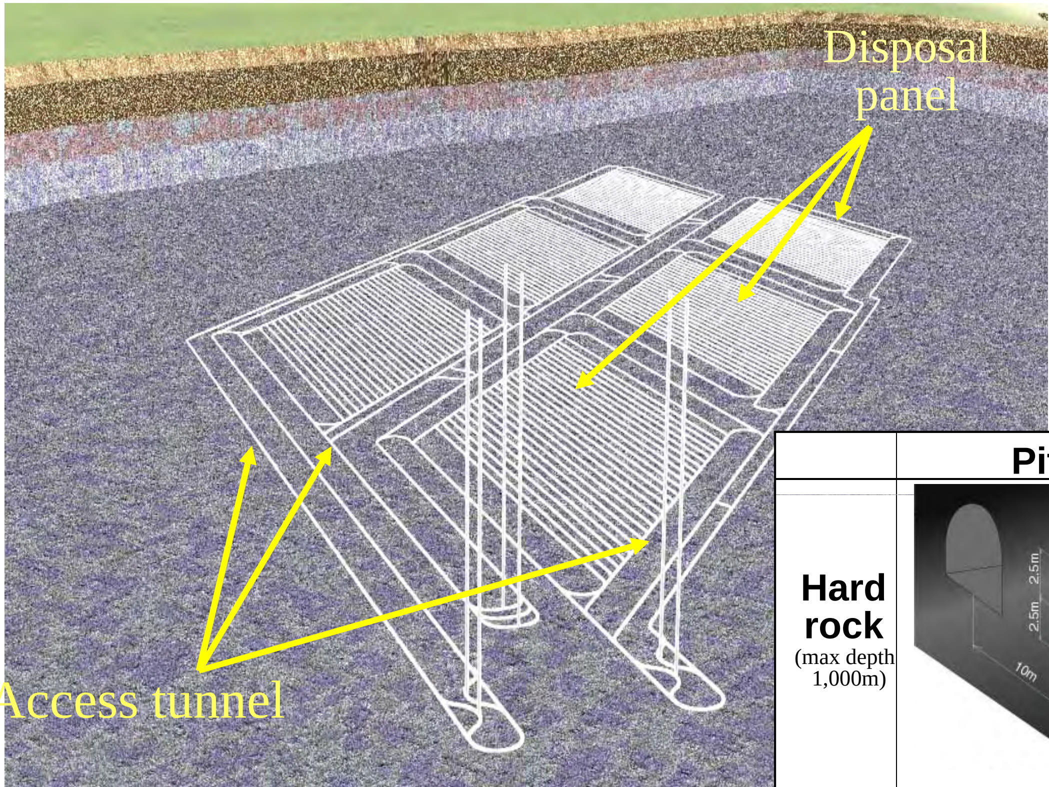
Advanced Repository Concepts - General

- Studies carried out over the last couple of decades have shown that many different combinations of waste type / engineered structures and geological settings can provide high levels of safety.
- In the past, there have been two main types of implementation strategy:
  - Given a site (e.g. in the vicinity of waste production), tailor a reference disposal concept to it;
  - Assuming a reference disposal concept, select a suitable site that will make its implementation easier.
- A better approach may be to specify key barrier functions, materials and operational goals and encourage flexibility to refine the design as the project moves towards implementation (or even after operation has commenced), building on experience gained.
- An integrated design procedure for optimization
  - the design engineers work closely with the PA, site characterization and public communication teams to ensure that the concepts developed are not only safe, but also practical, acceptable and cost-effective

Advanced Repository Concepts - Japanese Case

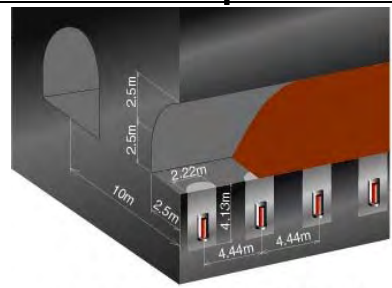
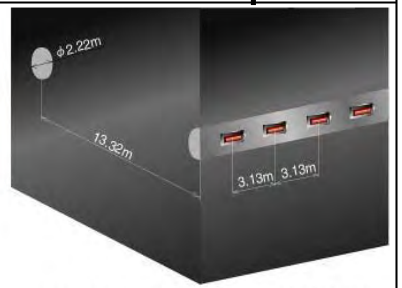
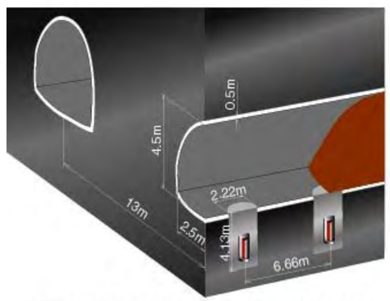
- A flexible design process is a particular characteristic of the HLW program
  - The decision to proceed with siting based on a call for volunteers
  - Although the original generic H12 concept and its variants, which were established for initial feasibility demonstration still remain a focus and define the main engineered barrier system (EBS) components considered, additional design options have been proposed, taking account of international developments
  - These repository design options are summarized in a "Repository Component Catalogue", which illustrates components that can be assembled into complete systems, maximizing design flexibility

H12 Reference Design



Repository layout

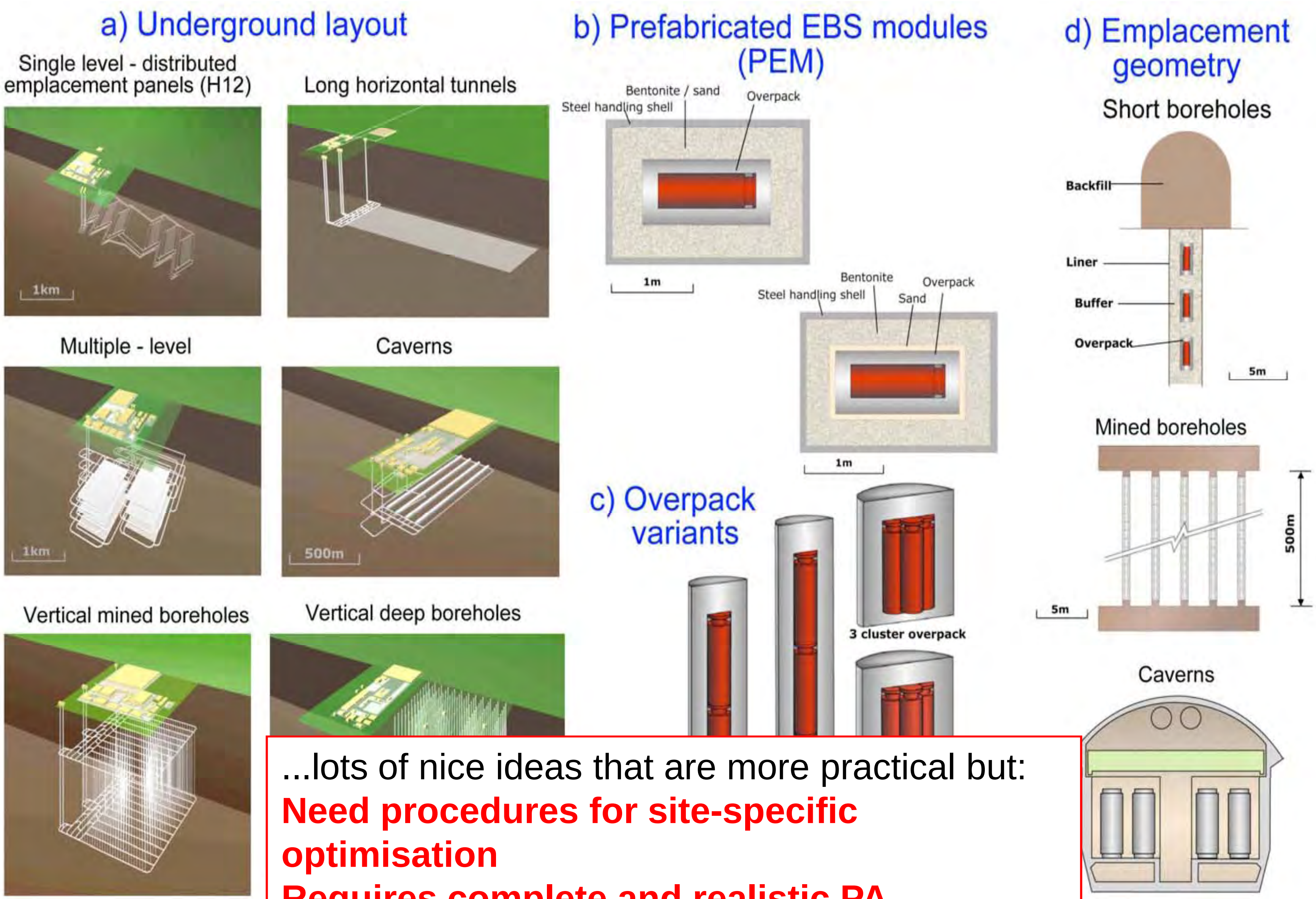
Emplacement of waste packages

	Pit disposal	Tunnel disposal
Hard rock (max depth 1,000m)		
Soft rock (max depth 500m)		

...simple generic design which is clearly impractical, but illustrates power of the robust EBS

Associated PA requires further simplification

"Repository Concept Catalogue" – menu of components

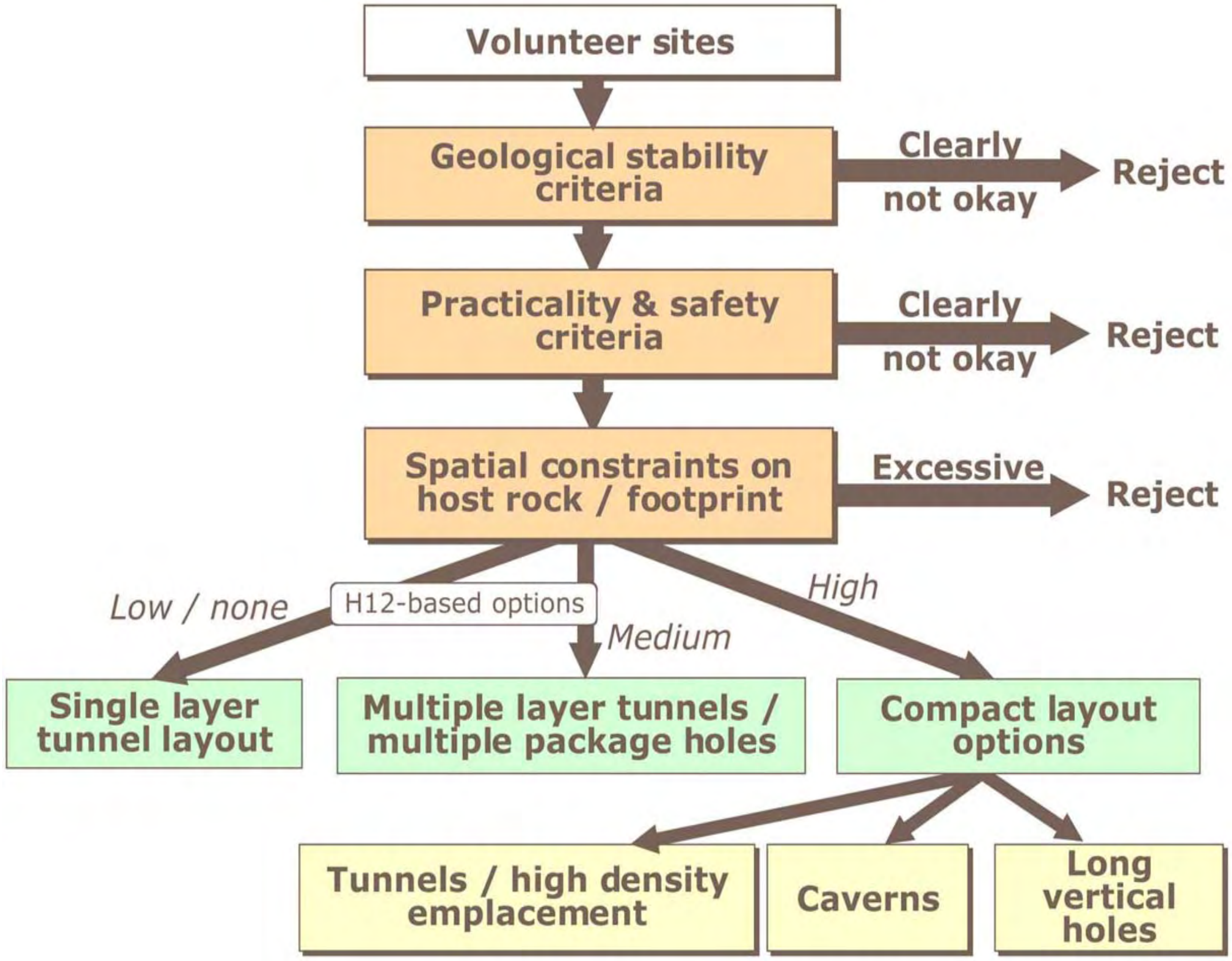


...lots of nice ideas that are more practical but:

Need procedures for site-specific optimisation

Requires complete and realistic PA

Evaluation of Constraints on a Site and Resultant Design Variants



Advanced Repository Concepts - Challenges

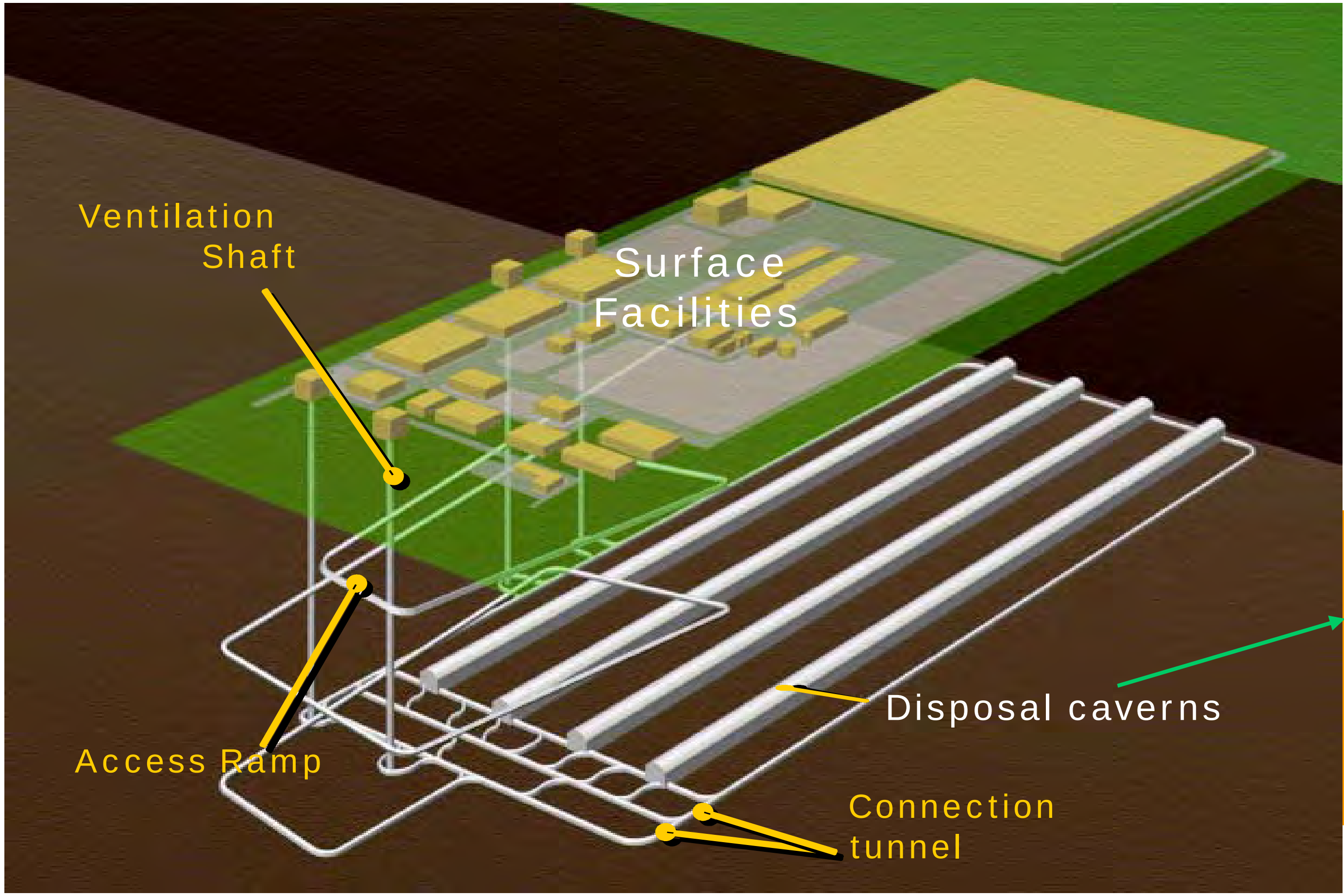
- To expand on these conceptual ideas, examining their advantages and disadvantages in different repository settings
- Such analysis will not only have to consider long-term safety, but also construction and operational safety, practicality, cost, public acceptability, etc.
- Since the repository concept report was published, there has been wide interest in some of the more novel conceptual designs and consideration of their application in various national programs (UK, Korea, USA, Canada, South Africa)
- This is thus clearly an area where interested countries could usefully collaborate – especially at early stages when much of the work is at a fairly generic level

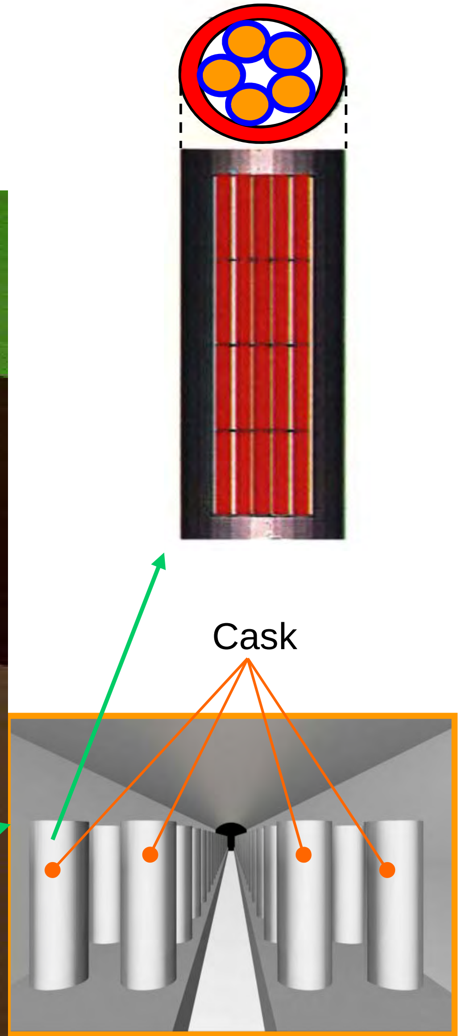
The CAvern REtrievable (CARE) concept

- An example of lateral thinking – still has H12 barriers but appears completely different
- Extended to include option of including other waste types and optimising for flexibility with regard to the total waste management strategy
- Emphasis on ease of retrieval (for some or all of the waste) over an extended time period (up to 300 years)
- Can be rapidly implemented based on existing technology, showing commitment to solution of the problem
- Can reduce costs and risks associated with surface storage
- Slow staging and long local involvement may increase benefit to – and acceptance by – the local community

Lateral thinking: Cavern Emplacement

A high emplacement density option for HLW –
Could this be combined with TRU disposal?



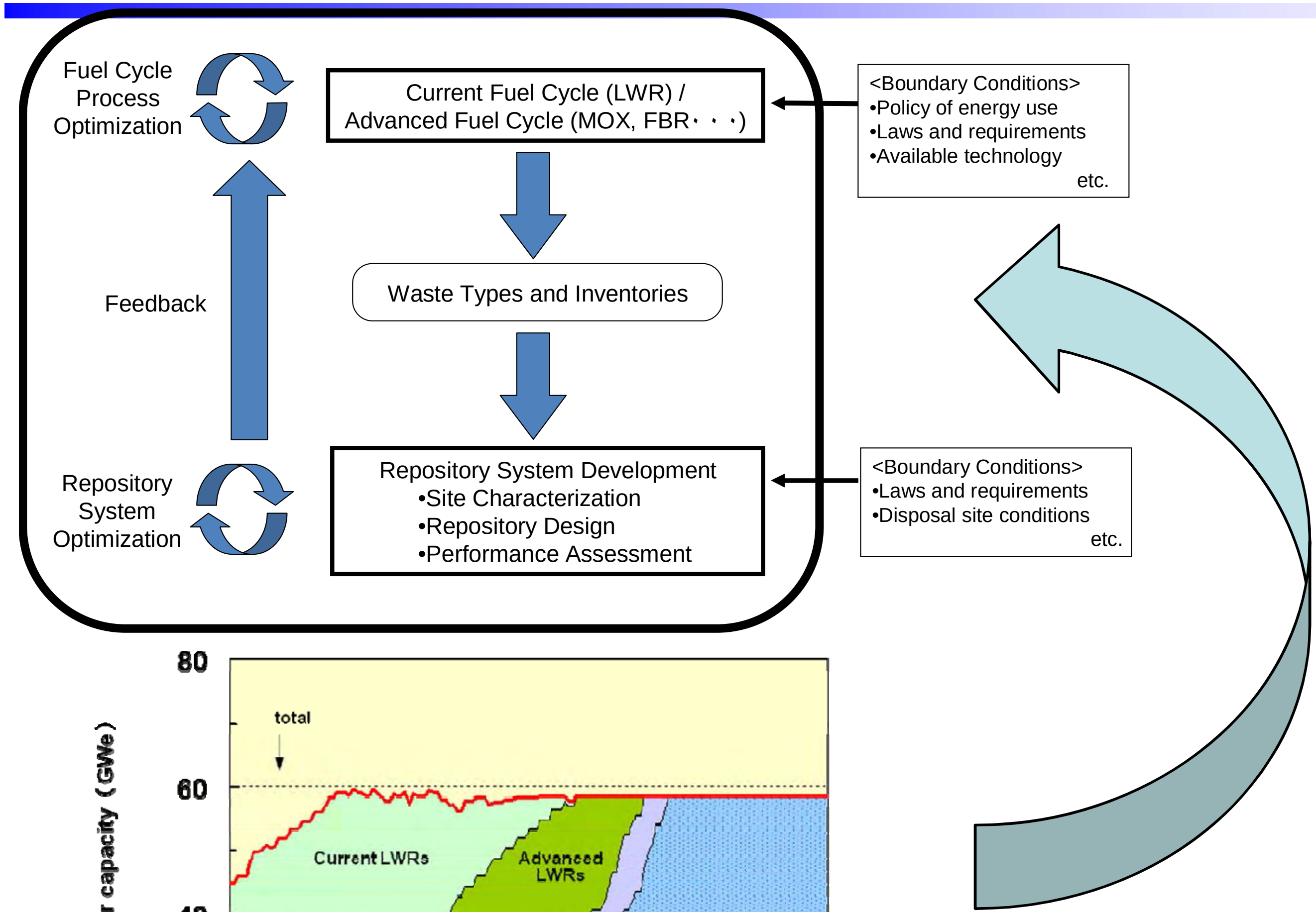


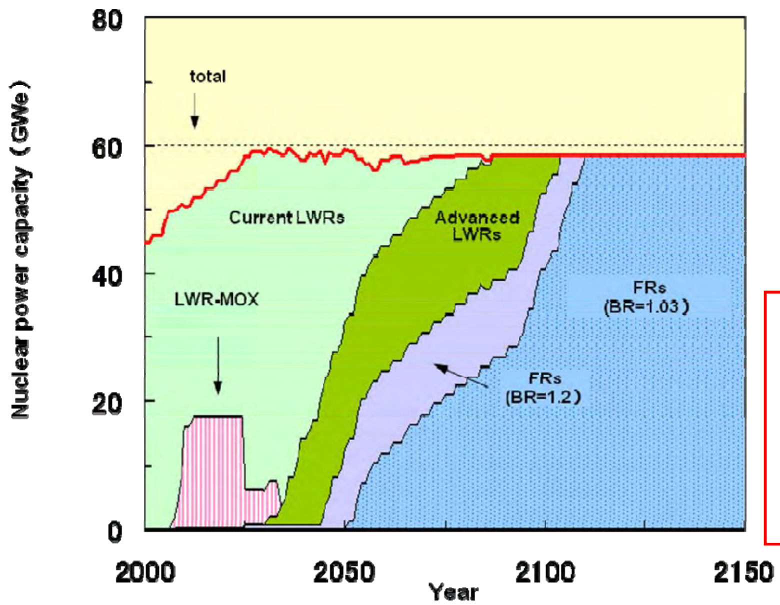
Disposal cavern

KM Challenges

- Extending the list of design options – facilitating innovation (potential application of TRIZ)
- Defining the inventories that establish boundary conditions
- Establishing a methodology for tailoring designs to future waste arisings (HLW & TRU) and specific sites – example of consideration of the use of concrete
- Establishing a next generation of realistic PA models to support such tailoring / optimisation – evaluation of boundary conditions set by computing power available
- QA – setting automatic change management as a function of model documentation (in following demo)

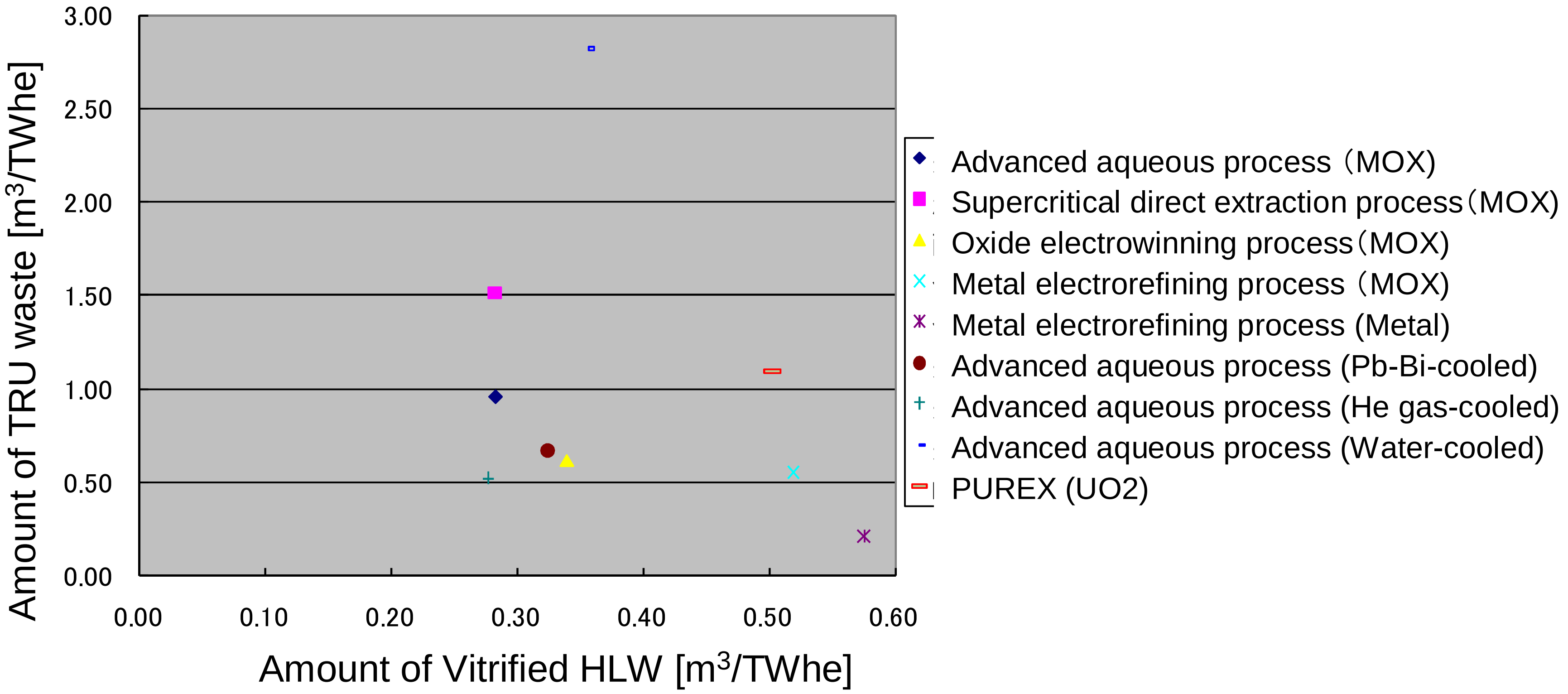
Inventory analysis





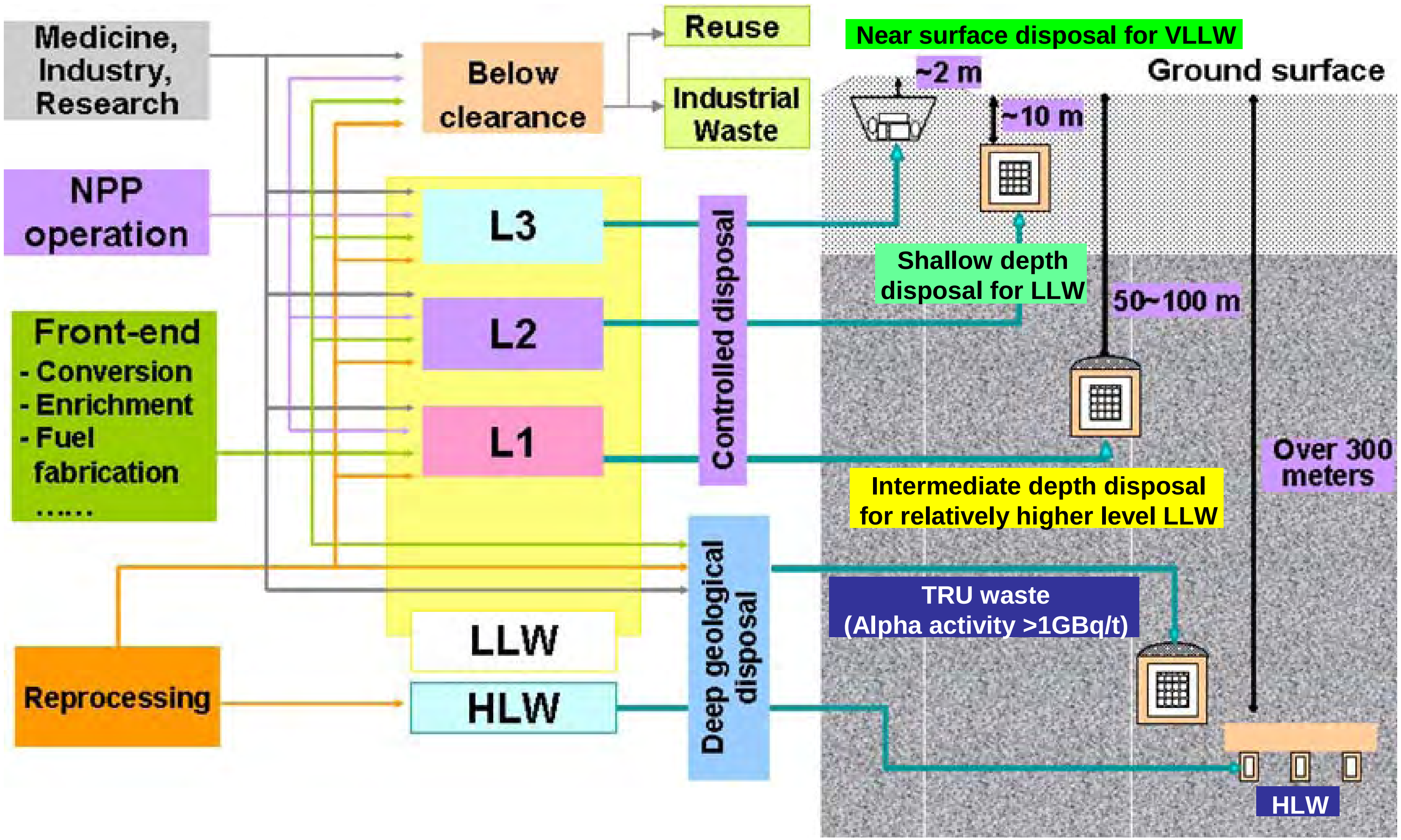
The nuclear renaissance is leading to intense discussion about future generations of reactors – but how can the back-end be optimised?

Developing the database



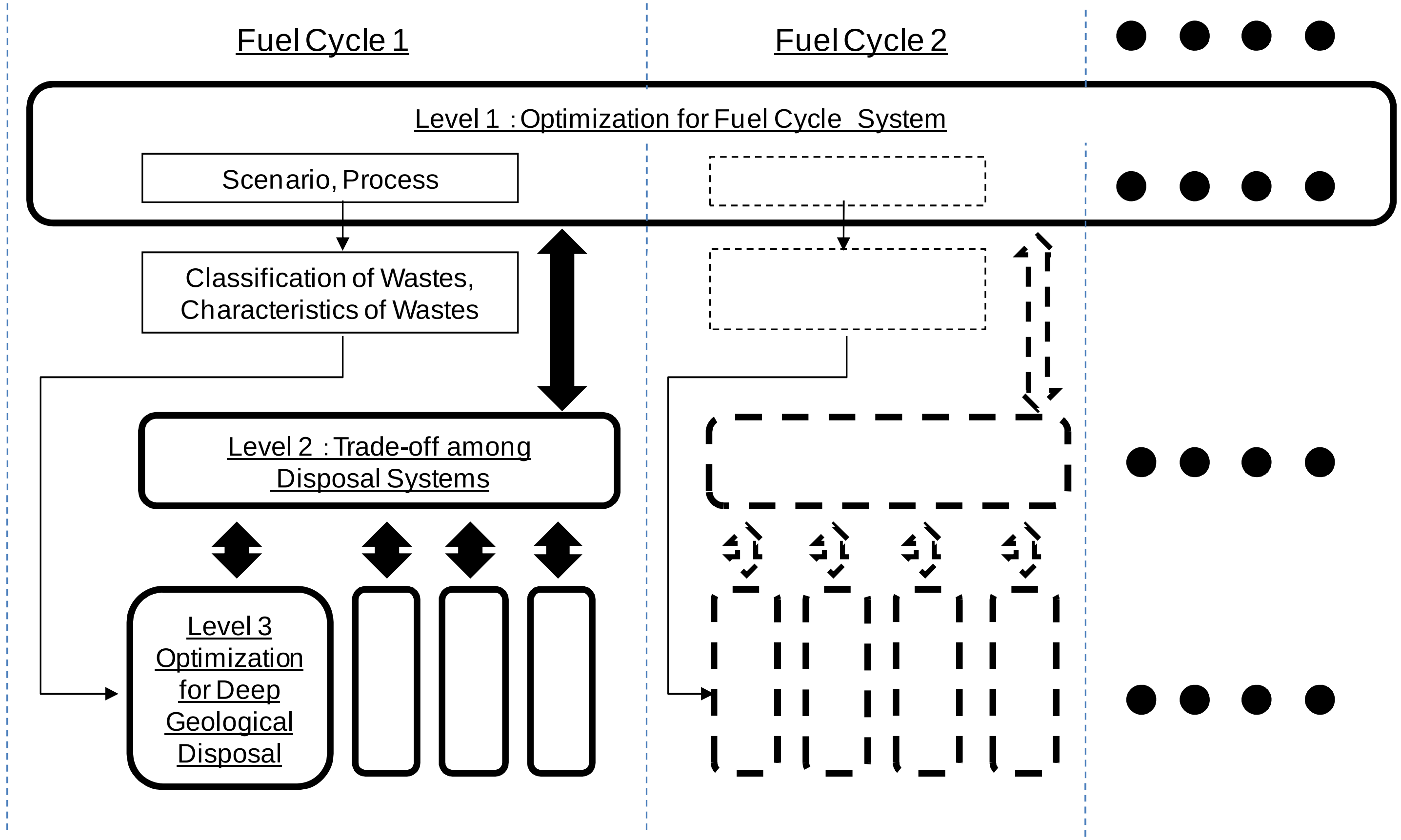
Various future reprocessing techniques give different balances of production of HLW and TRU – how does this influence total disposal costs?

...moving towards a holistic approach



Currently separate management depending on activity / origin of the waste
- Which leaves much room for optimisation

Optimisation process



A formal process is under development – currently the optimisation indicators are being considered and ways of measuring them examined

Design and Safety Assessment Toolkit & Databases - General

- Repository design for a given site
  - At early stages of the program
    - ✓ idealized designs only to show basic feasibility of construction and the likelihood of meeting regulatory guidelines
  - Mature project
    - ✓ special emphasis on maintaining local acceptance
    - ✓ other factors
      - operational safety
      - QA
      - ease of understanding of safety case by a non-technical audience
      - reversibility at early stages of implementation
      - cost (and resultant flexibility for providing local economic incentives)
      - repository footprint
      - etc

The evolving designs need to be more rigorous and, in particular, explicit trade-offs may need to be made when conflicting requirements are placed on the system

Design and Safety Assessment Toolkit & Databases - Challenges

- The challenges involve:
  - not only the range of widely differing factors when selecting between alternative design options, but also the uncertainties in most (or all) of the factors
  - the fact that some of these uncertainties will decrease with time, as the characteristics of the site become better defined - but surprises may occur and boundary conditions may change in an unpredictable manner
- An important part of justifying any particular design is to demonstrate:
  - a wide range of potentially suitable alternatives have been considered
  - the selected option represents, in some sense, “an optimum choice” or “better solution”, taking into account a range of relevant factors
  - The fact that a particular system has been studied for decades is no longer, in itself, sufficient justification to avoid looking at alternatives

Example of structured analysis

- It is increasingly recognised that H12-type HLW designs that avoid or minimise the use of concrete may be impractical for expected Japanese repository conditions
- The presence of concrete is completely ignored in the H12 performance assessment, but now well recognised to introduce many complications (e.g. NUMO TR-04-05)
- Complications also noted for TRU, particularly designs incorporating bentonite barriers
- With the assumption that potential problems will be minimised, extensive work is now focused on “low pH cement” formulations

Argument classes and numbering used (as before)

A1:Argumentation based on fundamental law of science

A2:Argumentation based on accepted principles

A3:Exclusion based on defined criteria

B1:Argumentation based on experimental data

B2:Quantitative prediction based on fundamental models

B3:Quantitative prediction based on empirical models

B4:Argumentation based on analogy

B5:Argumentation based on interpolation

B6:Argumentation based on extrapolation

B7: Argumentation based on expert judgment

C1:Argumentation of conservatism

C2:Argumentation of completeness

C3:Argumentation of robustness

D1:Argumentation based on common understanding

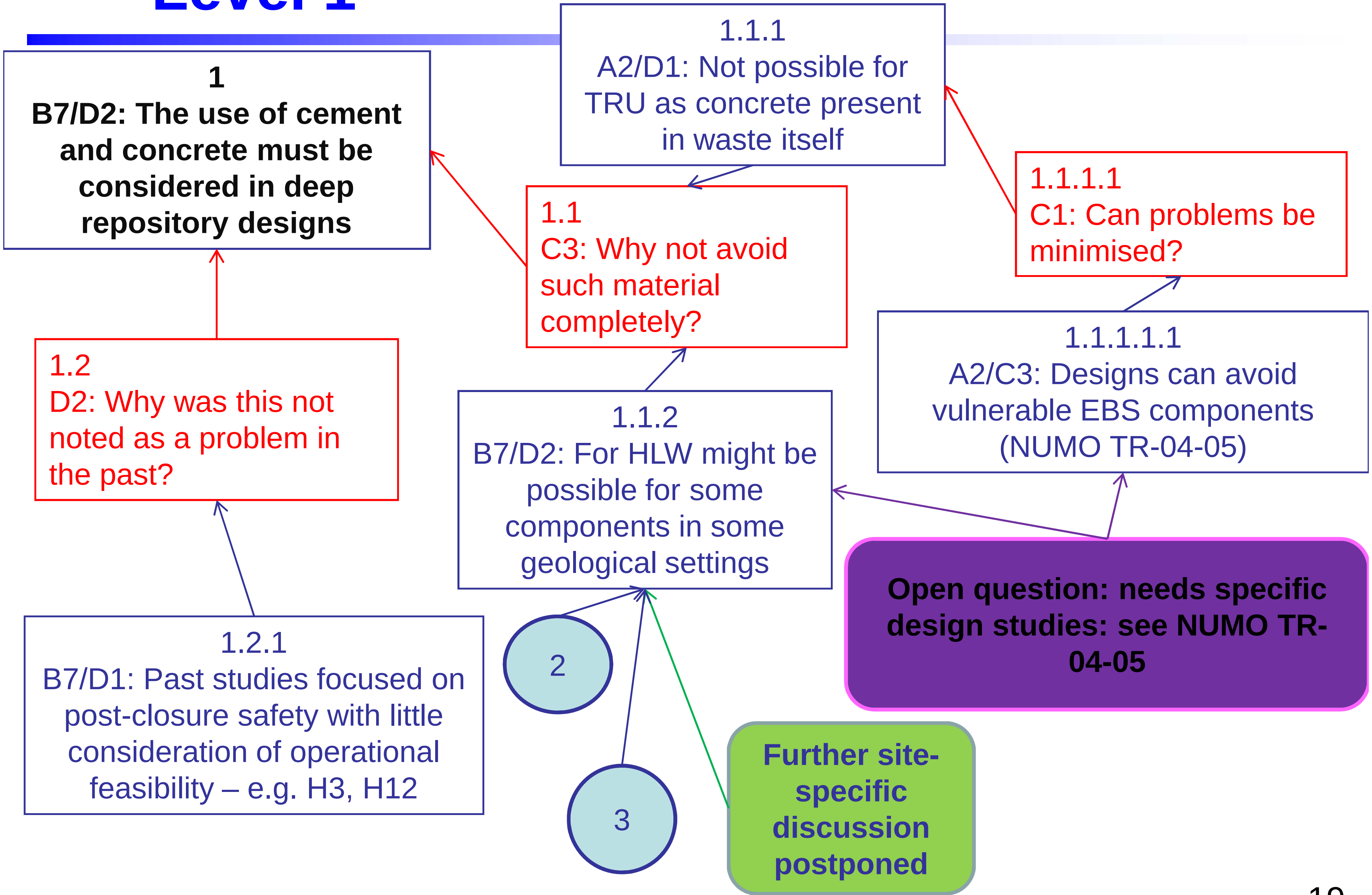
D2:Argumentation based on precedence

D3:Argumentation based on ethics

D4:Argumentation based on economics

D5:Argumentation based on public acceptance

Level 1


1
B7/D2: The use of cement and concrete must be considered in deep repository designs
1.1.1
A2/D1: Not possible for TRU as concrete present in waste itself
1.1
C3: Why not avoid such material completely?
1.1.1.1
C1: Can problems be minimised?
1.1.1.1.1
A2/C3: Designs can avoid vulnerable EBS components (NUMO TR-04-05)
1.2
D2: Why was this not noted as a problem in the past?
1.1.2
B7/D2: For HLW might be possible for some components in some geological settings
Open question: needs specific design studies: see NUMO TR-04-05
1.2.1
B7/D1: Past studies focused on post-closure safety with little consideration of operational feasibility – e.g. H3, H12
2
3
Further site-specific discussion postponed

Level 2

2
B7: If concrete used in a HLW repository, low pH formulations may be favourable (Low alkali cement – LAC)

2.1
D2: What are the benefits?

2.1.1
A1: Less thermodynamic incompatibility with EBS and NBS materials

2.1.1.1
C3: What are the critical components?

2.1.1.1.1
C2: EBS, bentonite & glass

2.1.1.1.2
C2: Host rocks; tuff and clay

Interface with JAEA Knowledge Base

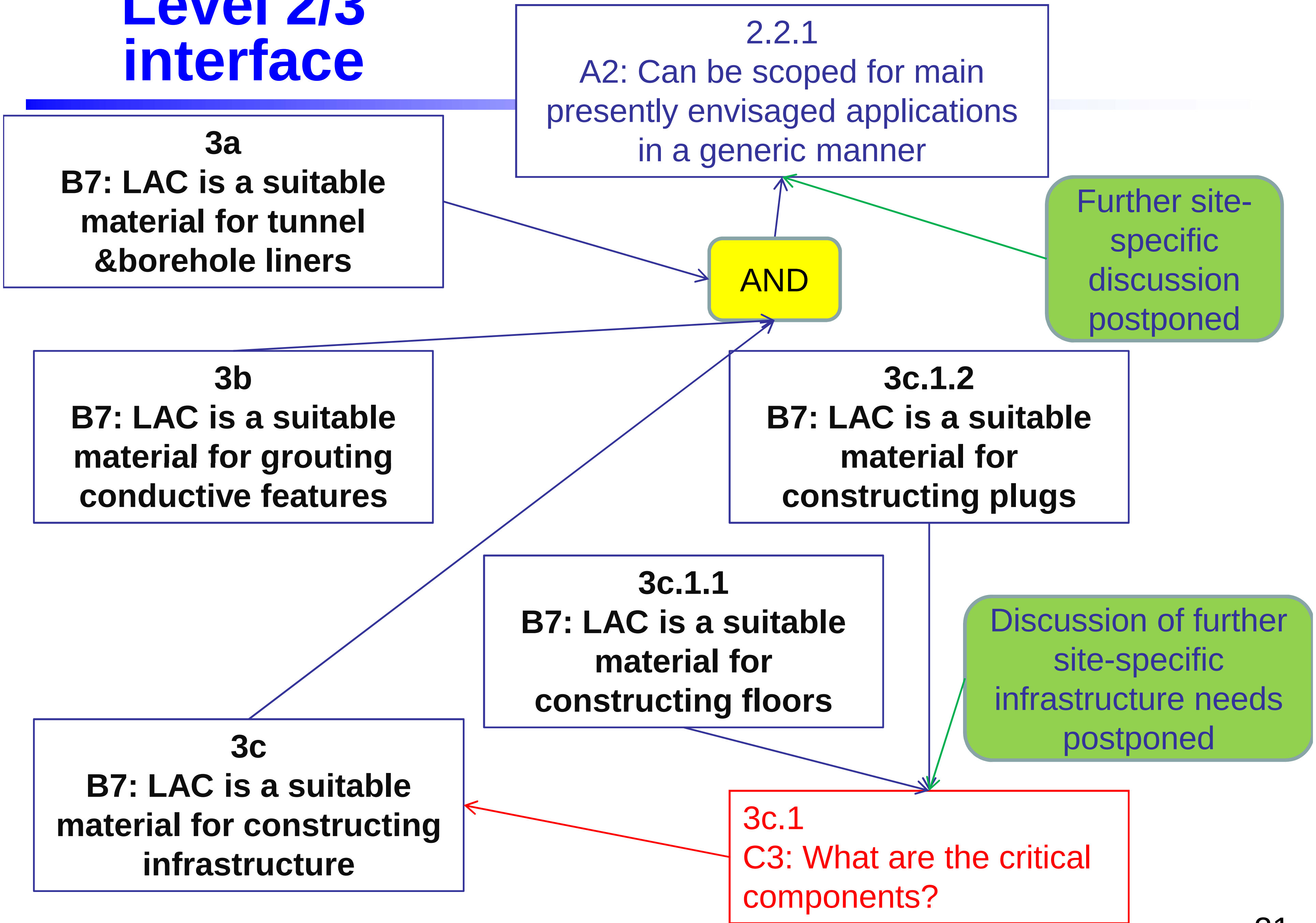
2.2
D1: Does this not depend on application?

2.2.1
A2: Can be scoped for main presently envisaged applications in a generic manner

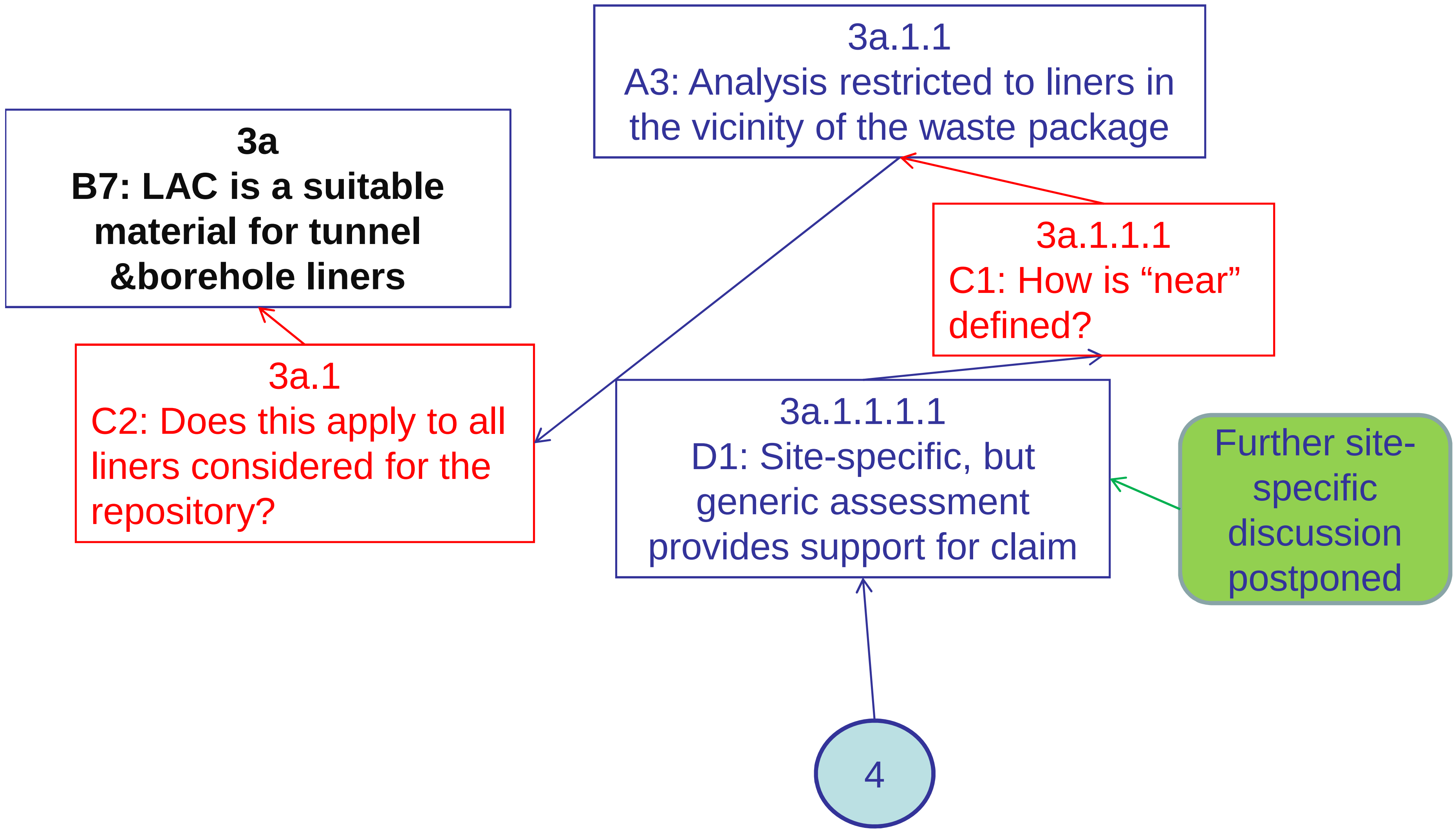
3

Further site-specific discussion postponed

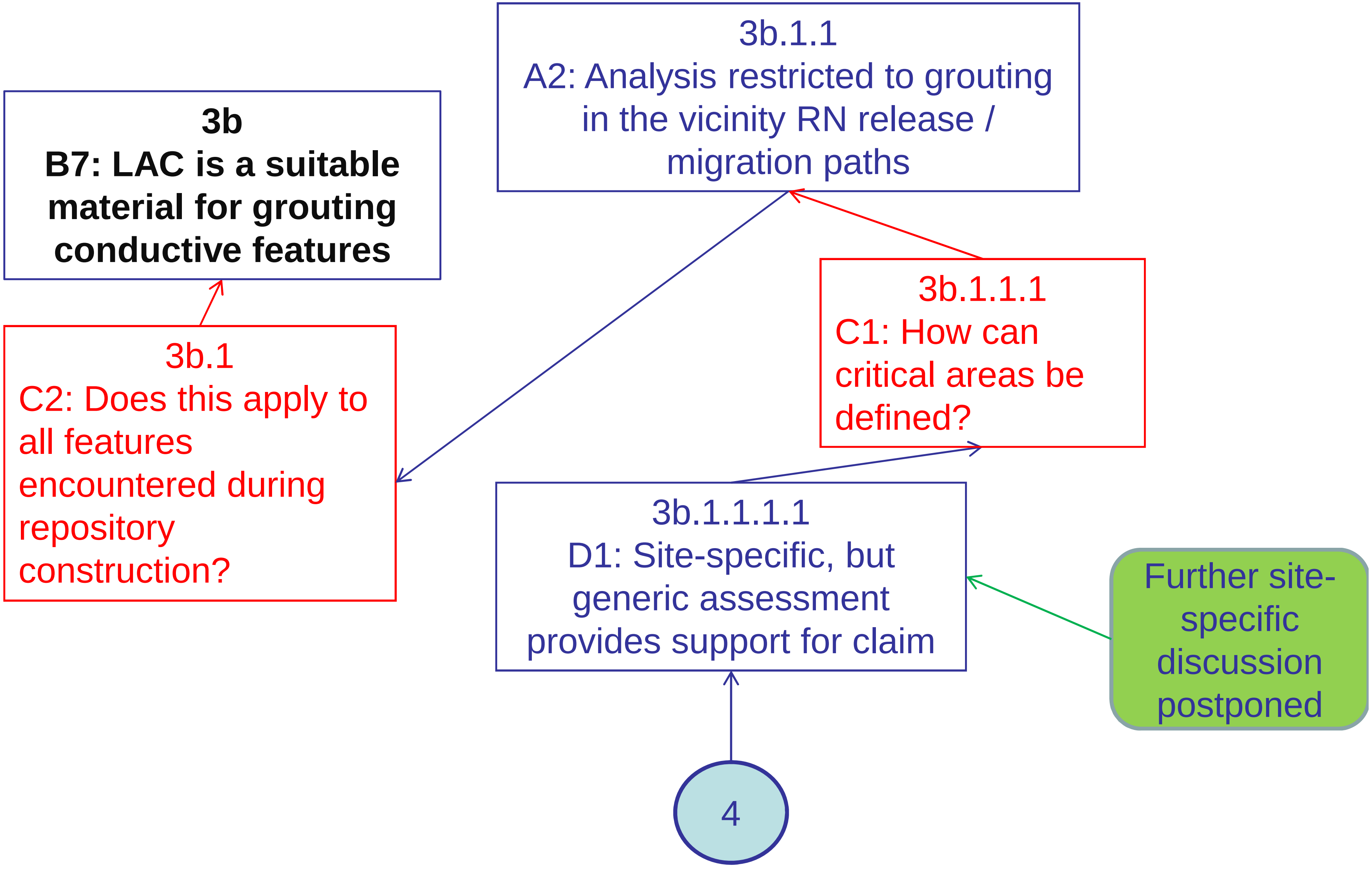
Level 2/3 interface



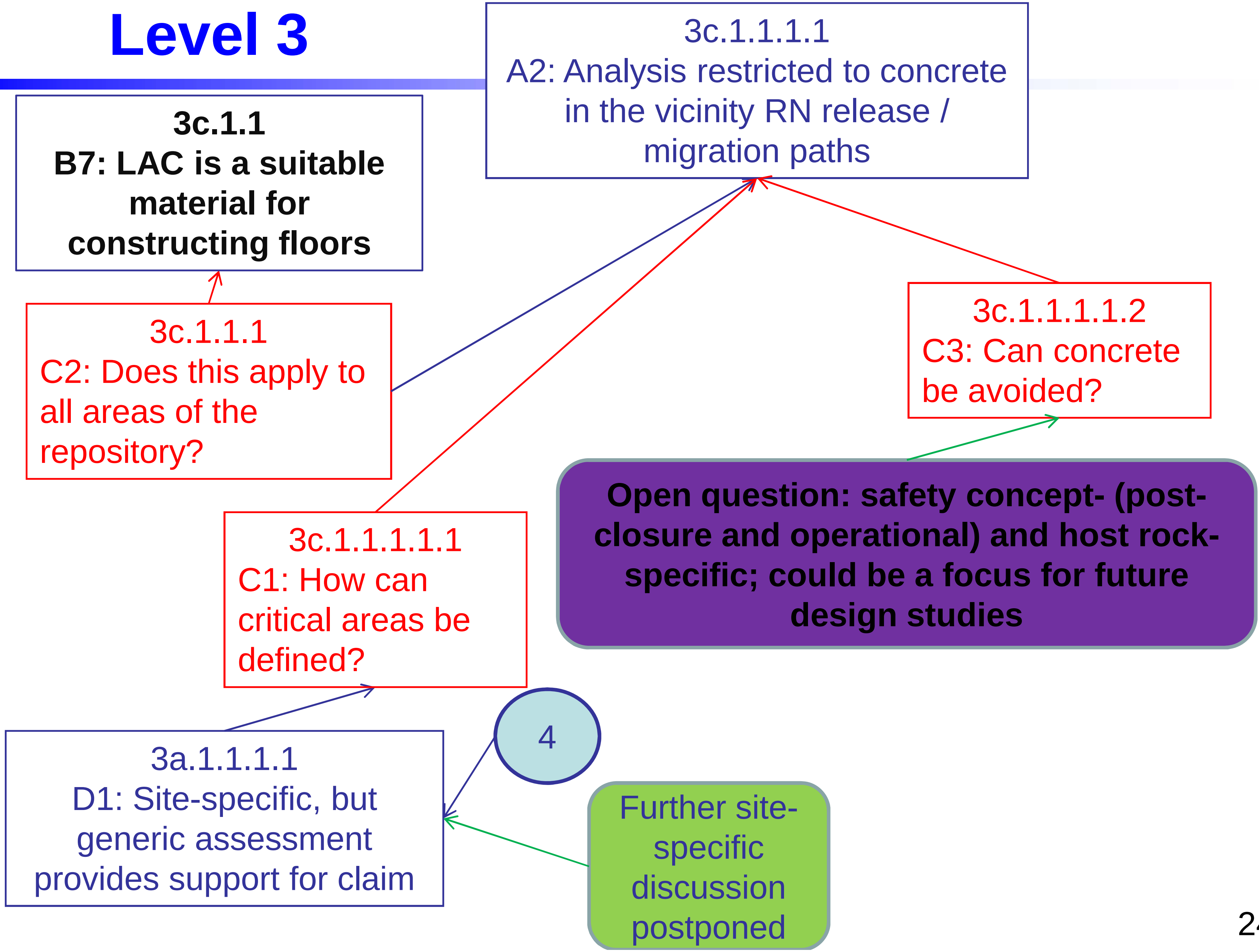
Level 3


3a
B7: LAC is a suitable material for tunnel &borehole liners
3a.1.1
A3: Analysis restricted to liners in the vicinity of the waste package
3a.1.1.1
C1: How is “near” defined?
3a.1
C2: Does this apply to all liners considered for the repository?
3a.1.1.1.1
D1: Site-specific, but generic assessment provides support for claim
Further site-specific discussion postponed
4

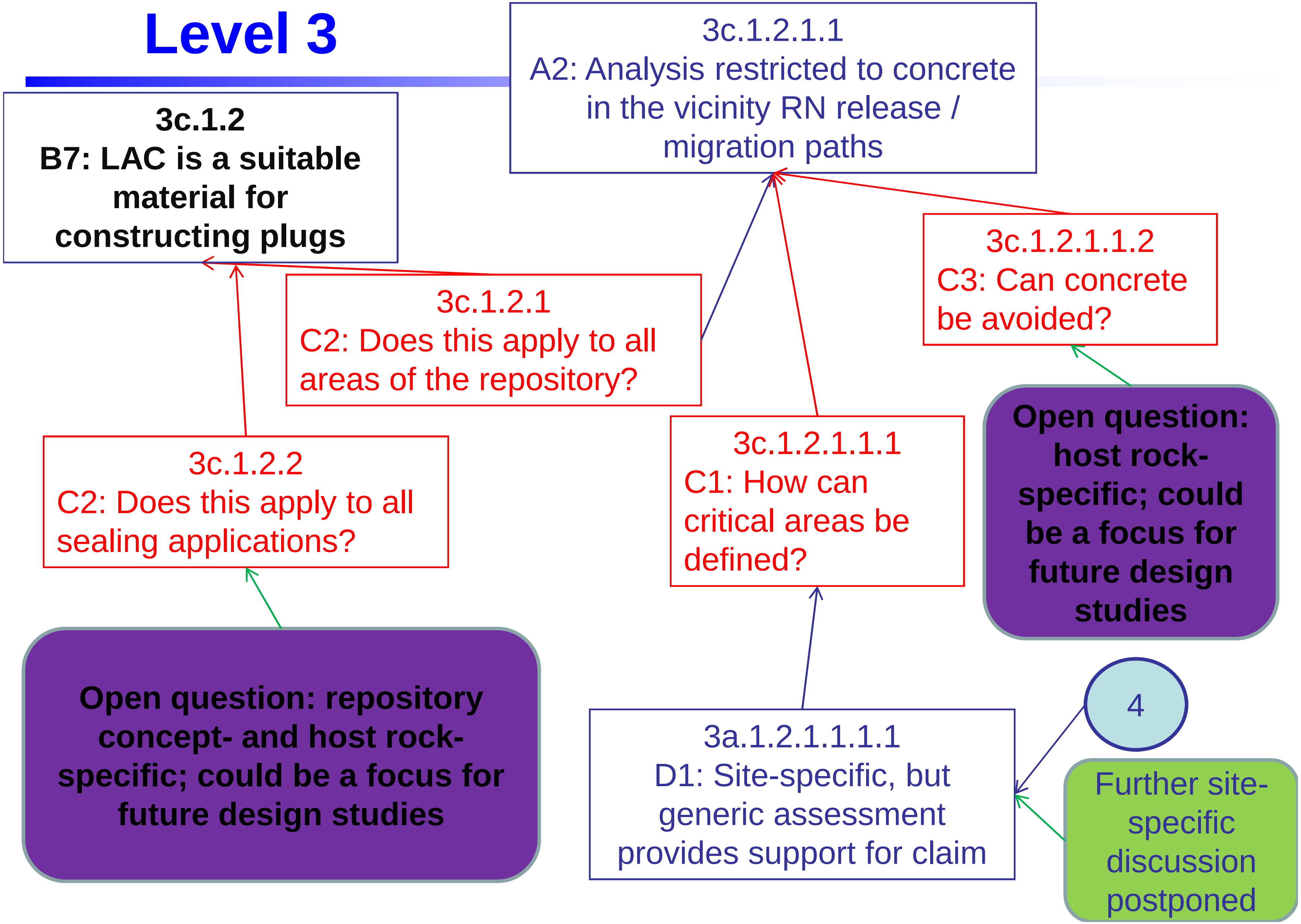
Level 3


3b.1.1
A2: Analysis restricted to grouting in the vicinity RN release / migration paths
3b
B7: LAC is a suitable material for grouting conductive features
3b.1.1.1
C1: How can critical areas be defined?
3b.1
C2: Does this apply to all features encountered during repository construction?
3b.1.1.1.1
D1: Site-specific, but generic assessment provides support for claim
Further site-specific discussion postponed
4

Level 3


3c.1.1.1.1
A2: Analysis restricted to concrete in the vicinity RN release / migration paths
3c.1.1
B7: LAC is a suitable material for constructing floors
3c.1.1.1
C2: Does this apply to all areas of the repository?
3c.1.1.1.1.2
C3: Can concrete be avoided?
Open question: safety concept- (post-closure and operational) and host rock-specific; could be a focus for future design studies
3c.1.1.1.1.1
C1: How can critical areas be defined?
4
3a.1.1.1.1
D1: Site-specific, but generic assessment provides support for claim
Further site-specific discussion postponed

Level 3


3c.1.2.1.1
A2: Analysis restricted to concrete in the vicinity RN release / migration paths
3c.1.2
B7: LAC is a suitable material for constructing plugs
3c.1.2.1.1.2
C3: Can concrete be avoided?
3c.1.2.1
C2: Does this apply to all areas of the repository?
3c.1.2.2
C2: Does this apply to all sealing applications?
3c.1.2.1.1.1
C1: How can critical areas be defined?
Open question: host rock-specific; could be a focus for future design studies
Open question: repository concept- and host rock-specific; could be a focus for future design studies
3a.1.2.1.1.1.1
D1: Site-specific, but generic assessment provides support for claim
4
Further site-specific discussion postponed

Caveats

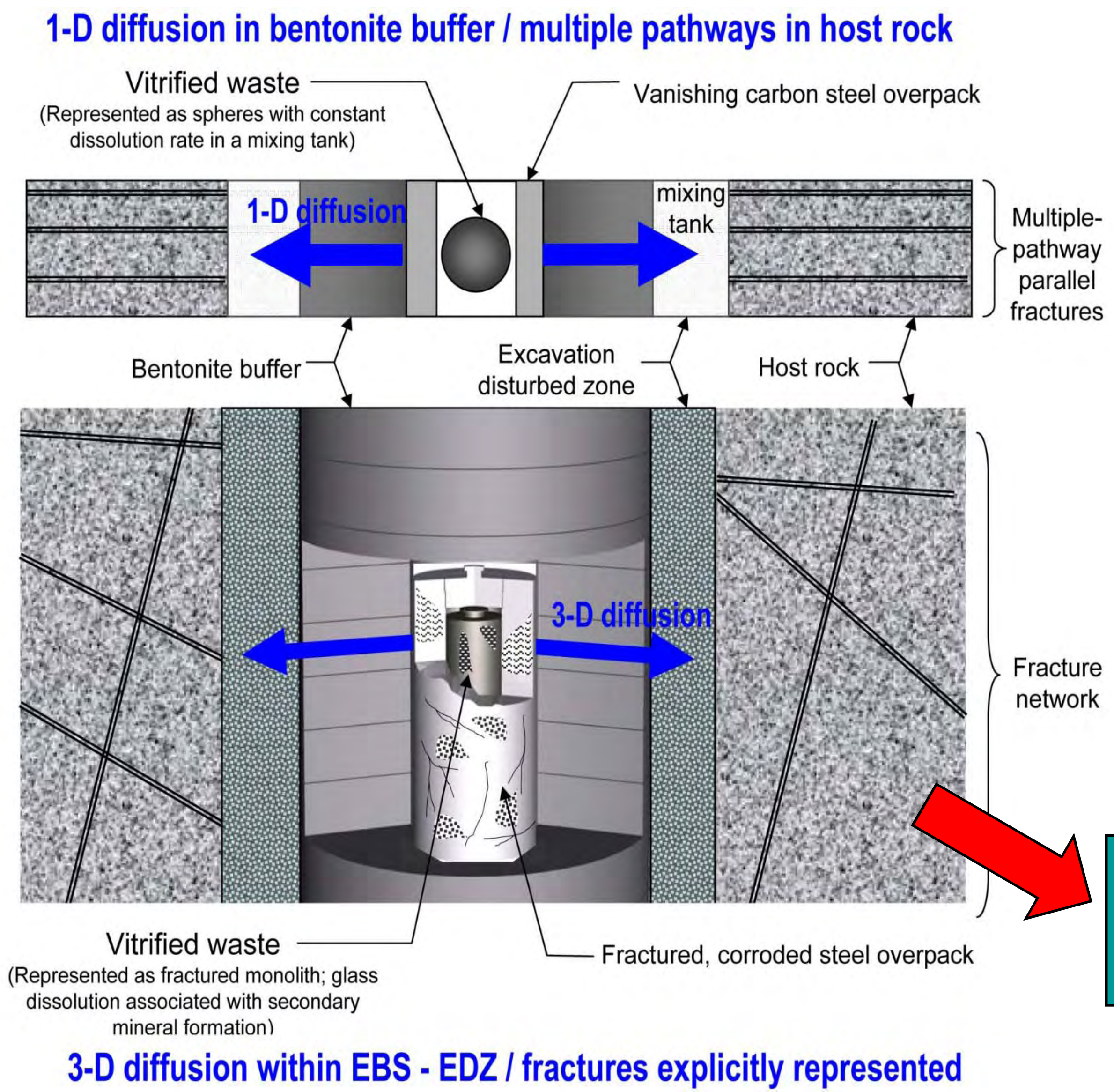
- Note that this is now getting extremely technical: the extent of fine technical detail required will depend on the extent to which questions can be left open (state of development of the safety case)
- Links to the KB identify the data needs and can be used to define or prioritise R&D if the existing knowledge is insufficient
- The argumentation network highlights points to be considered and can focus discussions between designers and PA groups

Next generation PA codes

Should be as complete and realistic as possible

- Represent all materials present and their interactions with each other
- Consider all components of the geosphere between the repository and the GBI
- Include all relevant processes together in the reference case (e.g. Colloids, microbes, gas, ...)
- Considers time evolution of materials and processes

Development of a More Realistic Model



H12 near field model

A more realistic representation of the safety barriers for HLW disposal

FULLY realistic model
-liner, backfill, cap, grout
- drainage, seals, ...

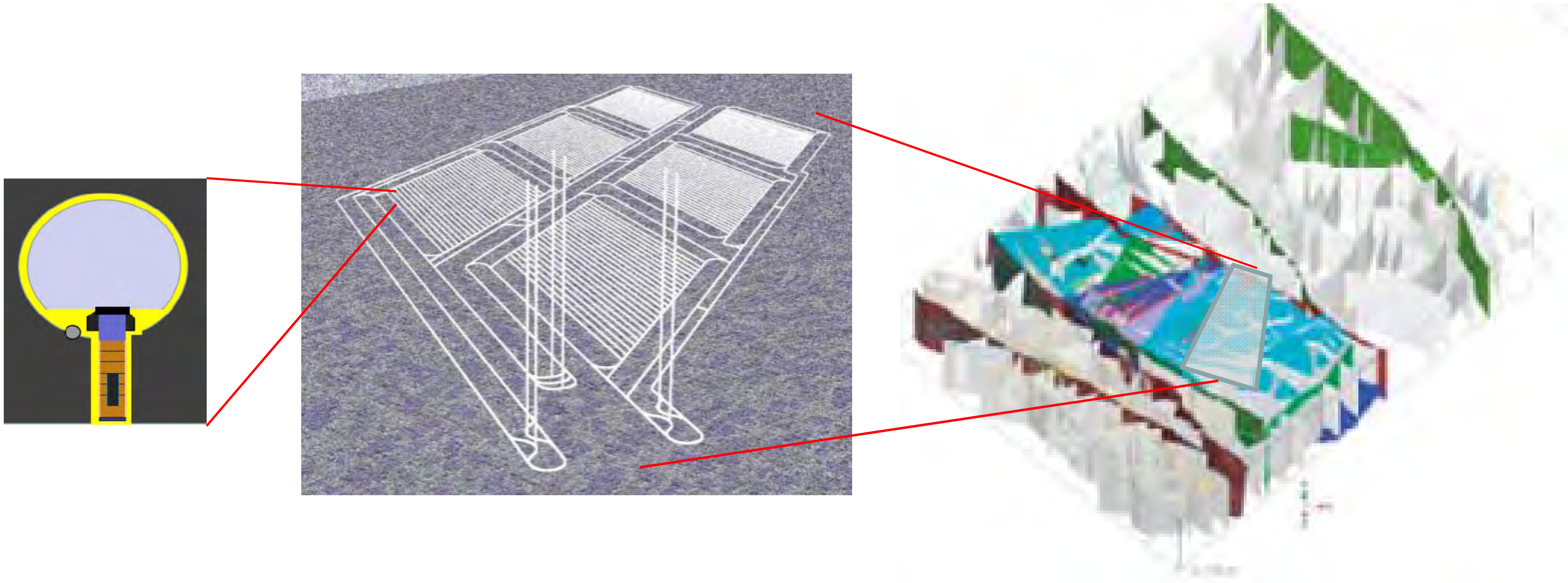
Development programme

- Check constraints set by available computing capacity – see following presentation)
- Establish capabilities of existing 3D time variable codes
- Determine data requirements and initiate KB searches, focused R&D
- Determine requirements for verification and validation
- Draft work programme to meet short term (e.g. PIA selection) and long-term (licensing) goals

The final goal

Technology and databases to allow

- Designs to be tailored to sites in a clear and transparent manner – for current and future waste arisings
- Optimisation with respect to operational & post-closure safety and other constraints
- Database for validation of key model components



Application of KMS Technology Toward Advanced PA: Design and Development

Workshop to Review the Progress of the Development of
a Knowledge Management System (KMS) and
Its Application toward Advanced
Performance Assessment (PA)

13-14 November, 2008
Tokyo

Hitoshi Makino

Outline of presentation

- Background and objectives
- Use of KMS to optimize knowledge creation and use in PA
  - Knowledge modeling
  - Blackboard architecture and hybrid system for PA
  - Example application: “All-in-one-report”
- Intelligent assistance for inventive problem solving for PA
  - Role of case studies
  - Case #1: Conceptual model development for uplift and erosion scenario
  - Case #2: Sensitivity analysis for computationally intensive problems

Block 1:

BACKGROUND AND OBJECTIVES

Challenges of KMS toward advanced PA (1/2) Optimization of routine tasks in PA

- Routine tasks in PA, e.g., flow and transport modeling, total system PA, development of input data set, interpretation of results, are repeated many times whenever there are changes in scenarios, repository design, geological environment models, relevant database etc.
- KMS support optimizing these tasks by
  - Assuring use of same ontology
  - Expediting communication among different disciplines
  - Highlighting "knock down effects" of changes in task flow
  - Storing all the relevant data and information in an easily accessible format
  - Delivering data and information to users when they are needed
  - Providing relevant knowledge in the form of rule-base or case-base
  - Recording all the changes for future reference

Challenges of KMS toward advanced PA (2/2) Innovation in problem solving for PA

- In a longer time-scale, though, PA is not simple reproduction of what we have been doing in the last decades
- Innovation in PA requires re-formulation of problems, development of new models and software, introduction of new technologies, etc.
- KMS could provide intelligent assistance for those innovation if
  - Mechanisms of inventive problem solving in the past are formulated in a generic format that can be applied to new problems
  - Knowledge engineering can support formulating and using knowledge for such inventive problem solving in a systematic manner

Approaches in Phase 1

Optimization of PA tasks

- Most of the concepts and key technologies in knowledge engineering (KE) are applicable
- Appropriate level of automation varies from task to task
- Multi-disciplinary collaborations are best supported by hybrid systems working in a blackboard architecture
- Prototype for demonstration and validation of the concepts are required in Phase 1

Innovation in problem solving

- Heavily dependent on experts' own ability and experience
- Automation is not the goal
- Intelligent assistance to experts' problem solving process is more practical target
- Case studies of innovative problem solving in PA provides opportunity to analyze and classify mechanisms of invention in Phase 1

Block 2:

USE OF KMS TO OPTIMIZE KNOWLEDGE CREATION AND USE IN PA

Knowledge modeling

- Activity First Method (AFM)
  - Start from describing entire flow of tasks
  - Define input/output of each task
  - Identify knowledge relevant to individual tasks
  - Model communication among different disciplines at different stages
- Use various types of interview for acquiring knowledge from experts
- Construct ontology as a common basis shared by experts from diverse disciplines and computers (intelligent systems)
- Model knowledge in an exchangeable manner between experts and intelligent systems

Procedure of knowledge modeling

Knowledge Acquisition

I. Task flow analysis

II. Acquisition of related knowledge items

Knowledge Modeling

III. Construction of ontology model in Protégé

VI. Syntax analysis of rules and cases

System Design

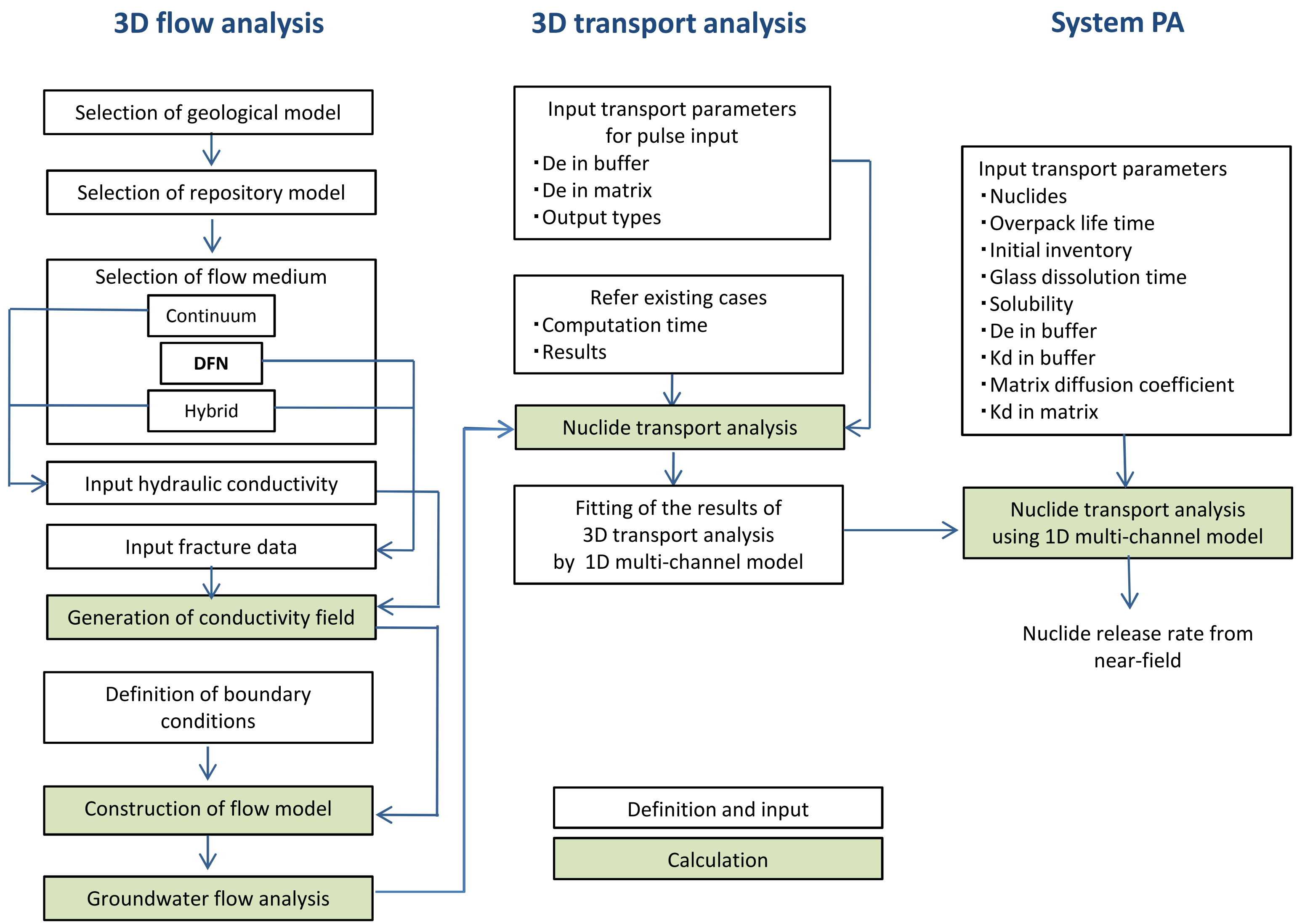
Expert System Development

V. Creation of an interface template and formulating knowledge elements as a menu, based on the results of syntax analysis.

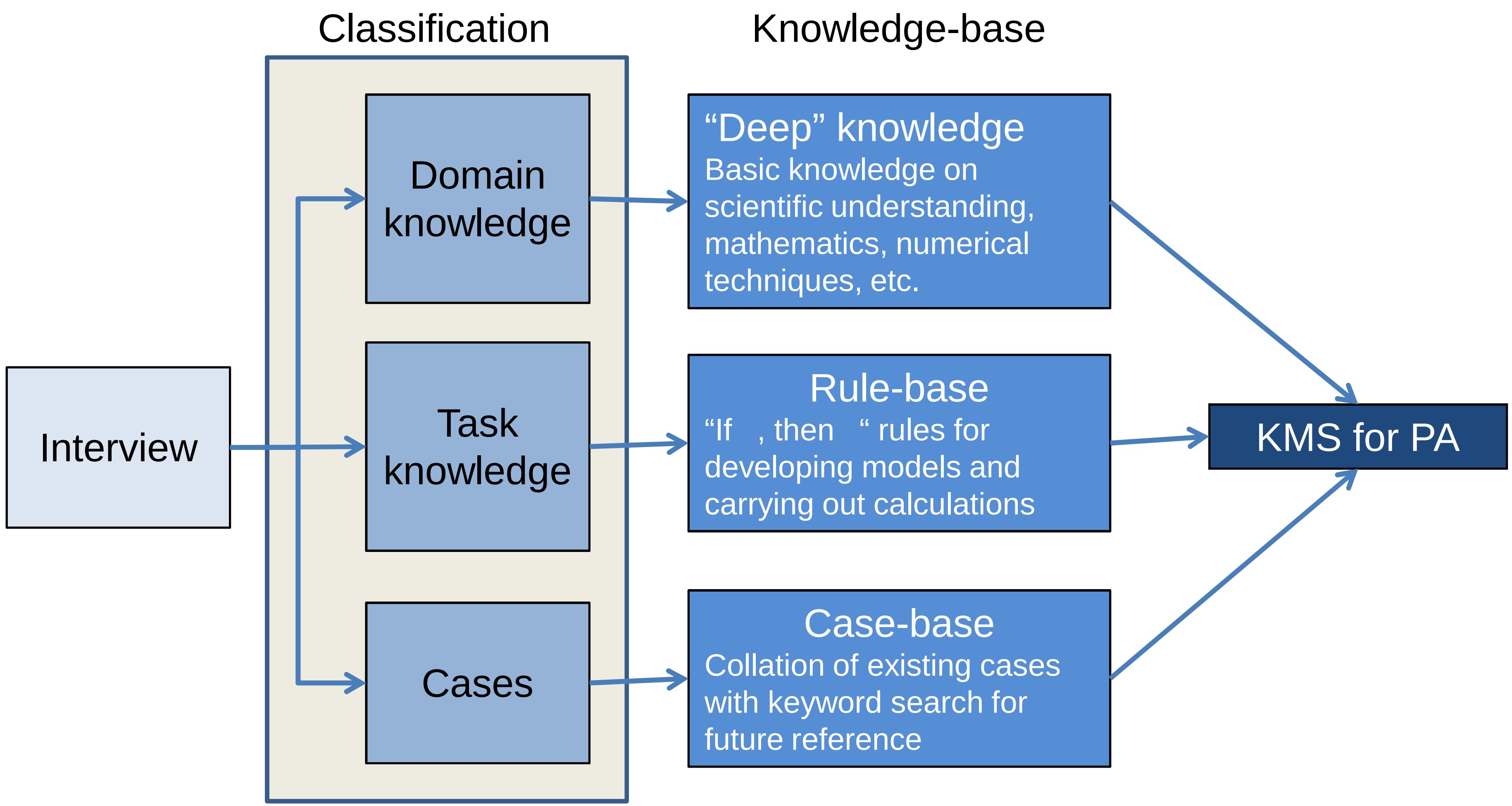
VI. An expert uses the interface in step “V” to create the rule base and case base by selecting knowledge elements and syntax.

VII. The expert system group is produced automatically.

Knowledge modeling : Task flow analysis



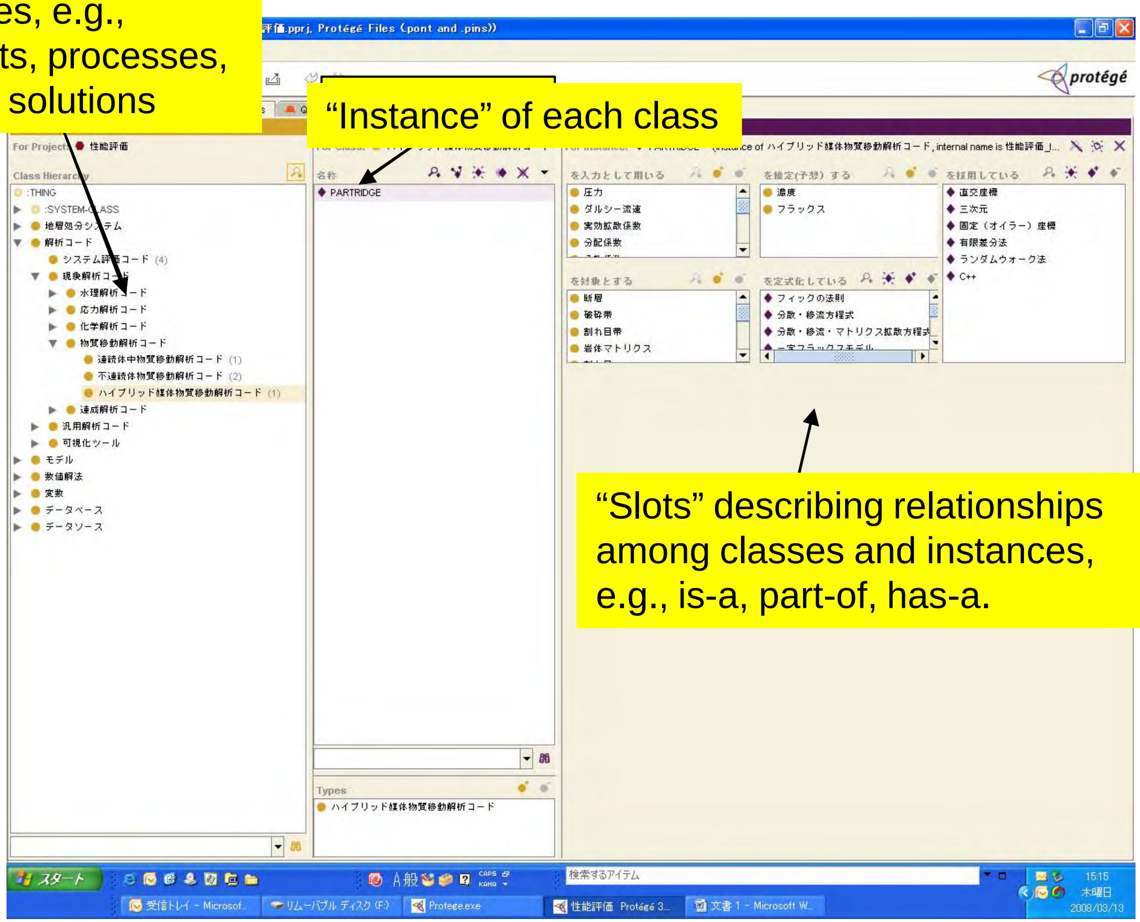
Knowledge modeling
Acquisition of knowledge relevant to PA tasks



Knowledge modeling
Construction of ontology model in Protégé

Hierarchy of classes, e.g., system components, processes, models, numerical solutions

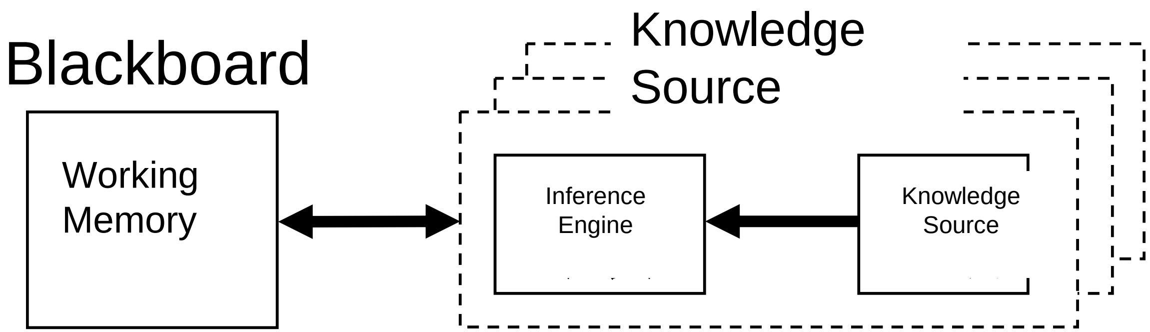
"Instance" of each class



"Slots" describing relationships among classes and instances, e.g., is-a, part-of, has-a.

Blackboard Architecture

- Problem Solving Model for Scholastic Organizations
- Organizes and displays a shared space where members of a group can view the results of the tasks of individual members and facilitate group cooperation.
- Benefits of using Blackboard Architecture:
  - Provides a problems solving framework based on knowledge integration.
  - Presents a hierarchical structure to express diverse, interrelated knowledge.
  - Aids application of inference engines and other knowledge engineering tools.
  - Offers improvements in development efficiency and maintainability when compared to a single, large-scale knowledge base.



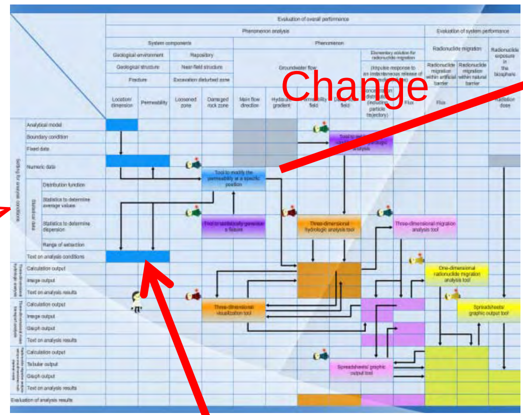
All-in-one-report: Basic concept

Report

HTML document including texts, tables, and figures representing information in relevant sub-regions of blackboard

Blackboard

Working memory including all the information and interim results relevant to the report



Control shell

Start appropriate KS and deliver required input when there are changes in blackboard

Revision of report = Mapping progress of blackboard

Texts

Tables and figures

New result

Input

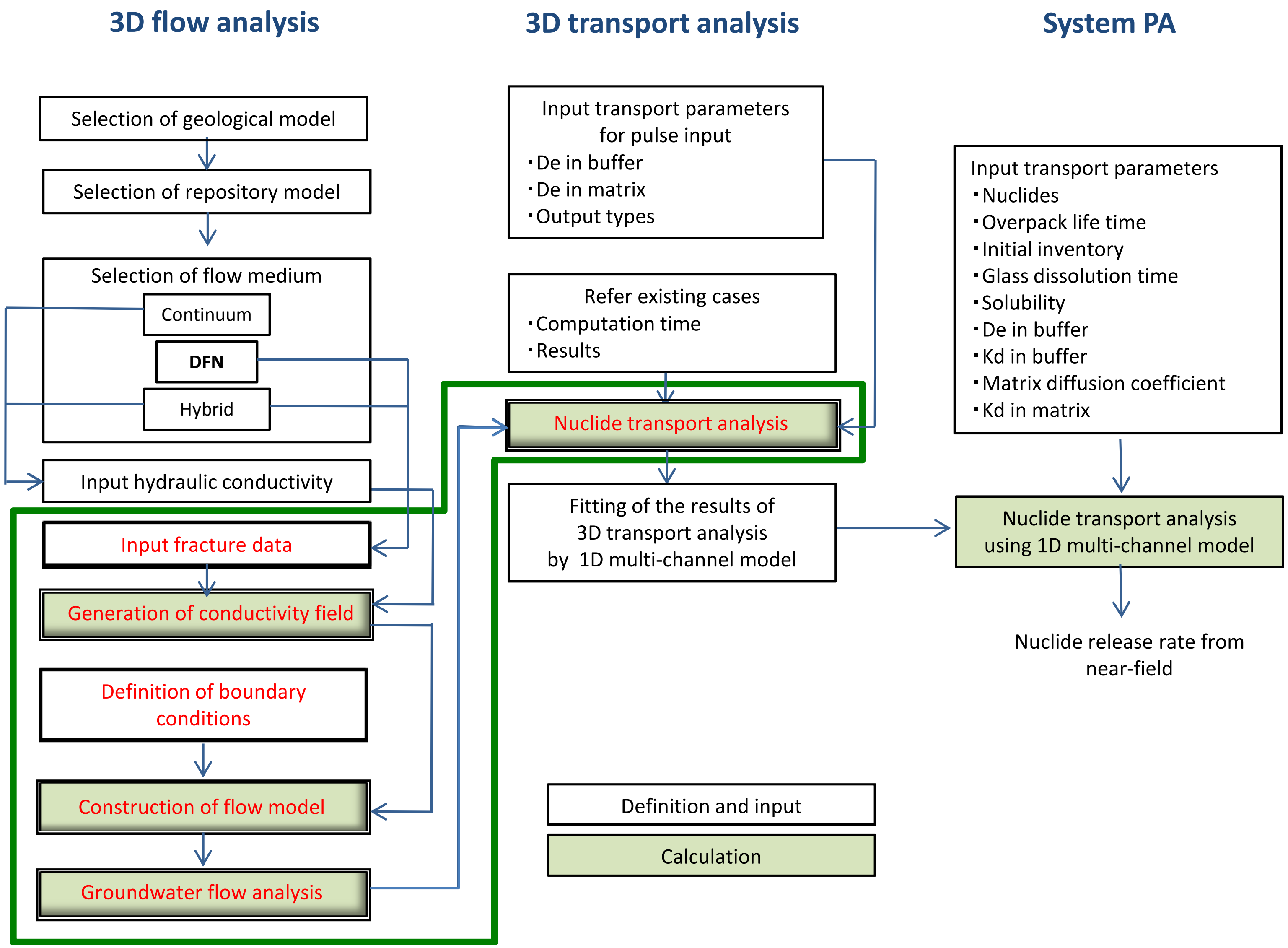
Knowledge source

Applications PA codes, visualization tools, etc.

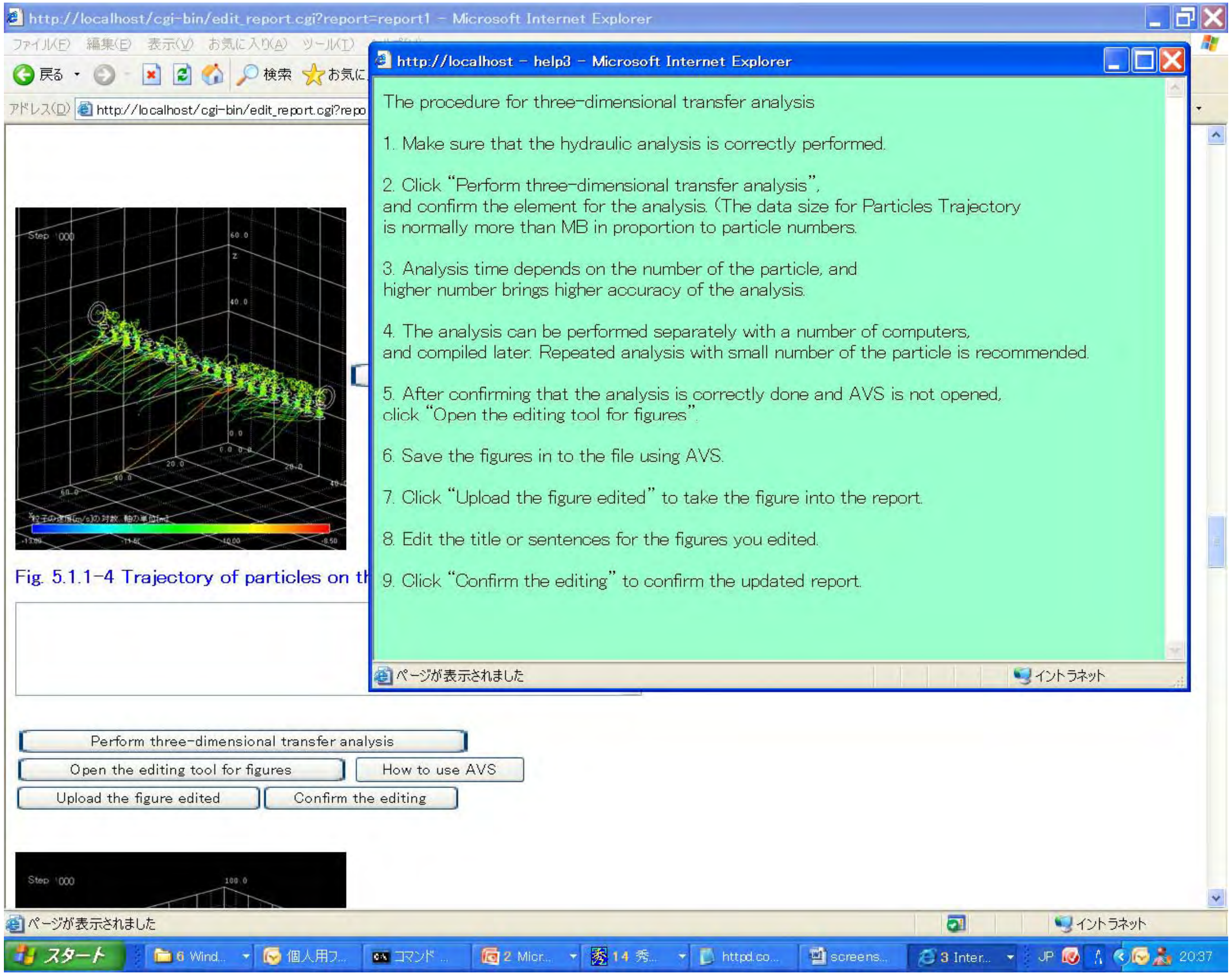
Intelligent system
- Expert systems
- Online help for use of applications
- Link to knowledge-base

User

Task flow covered in example of All-in-one-report

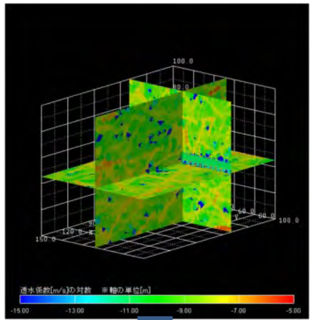


Revising report by following on-line guidance

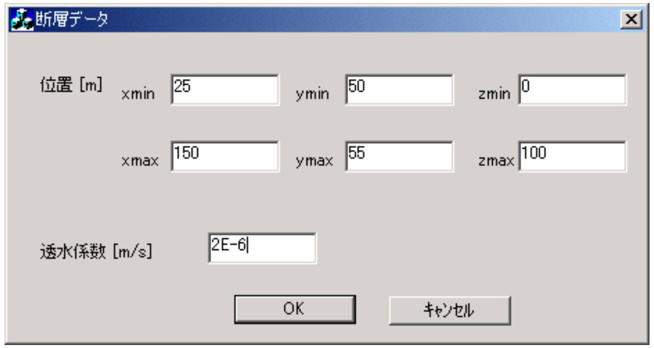


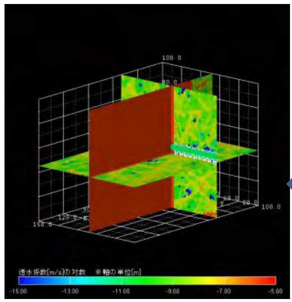
All-in-one-report: Behind the scene

User interface



Input to define changes, e.g., addition of a fault, in a pop-up window





Blackboard

Change material number of corresponding finite elements automatically

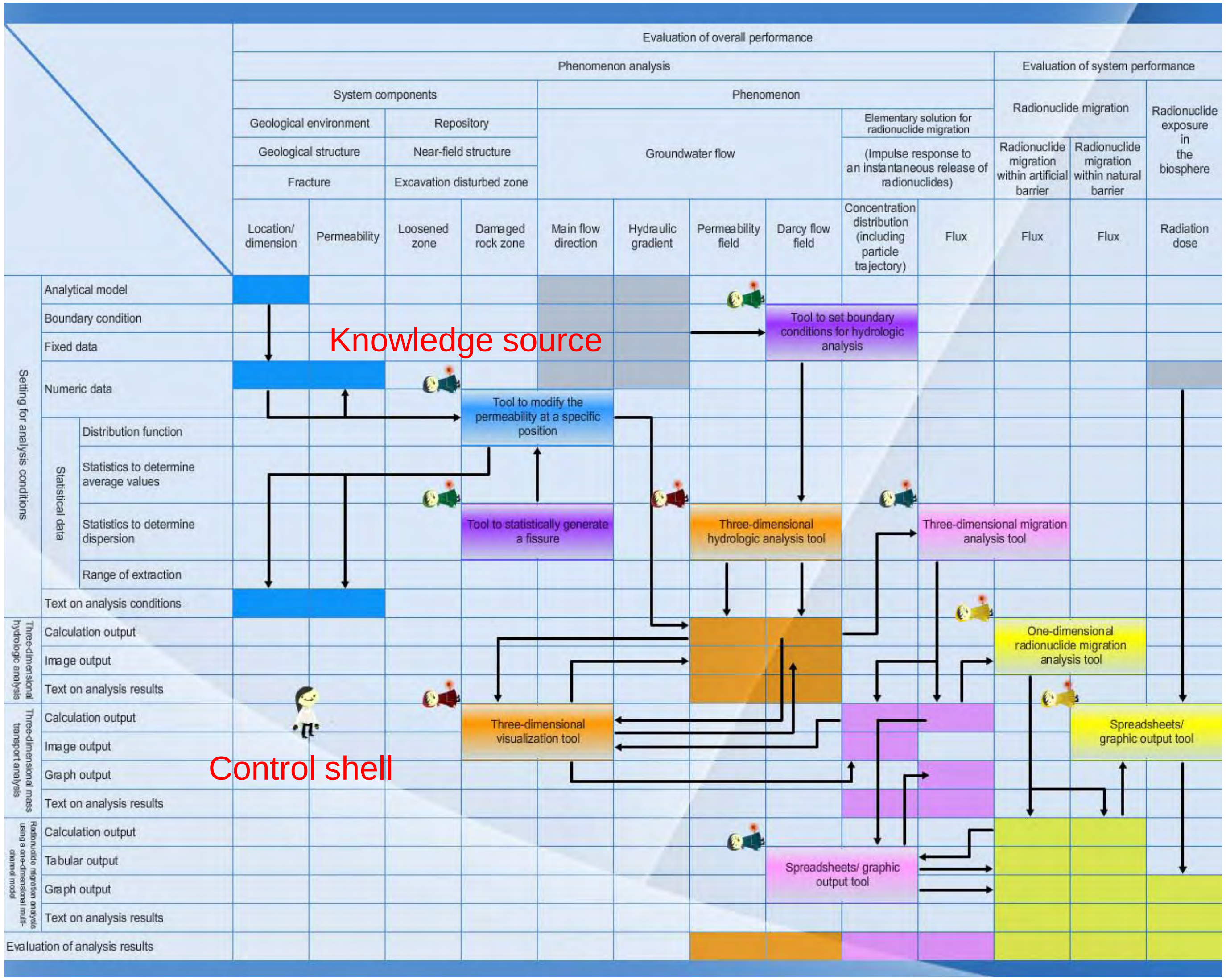
Before	After
1	9
2	10
4	9
7	10
6	9
8	9

xmin	ymin	zmin	xmax	ymax	zmax	
25.0	50.0	0.0	150.0	55.0	100.0	//
25.0	50.0	0.0	150.0	55.0	100.0	//
25.0	50.0	0.0	150.0	55.0	100.0	//
25.0	50.0	0.0	150.0	55.0	100.0	//
25.0	50.0	0.0	150.0	55.0	100.0	//
25.0	50.0	0.0	150.0	55.0	100.0	//

1e-11	1e-11	1e-11	0.0	0.0	0.0
1e-12	1e-12	1e-12	0.0	0.0	0.0
1e-12	1e-12	1e-12	0.0	0.0	0.0
2e-6	2e-6	2e-6	0.0	0.0	0.0
2e-5	2e-5	2e-5	0.0	0.0	0.0

Overwrite hydraulic conductivity data automatically

Appearance of knowledge sources and control shell on Blackboard monitor



Block 3:

INTELLIGENT ASSISTANCE FOR INVENTIVE PROBLEM SOLVING FOR PA

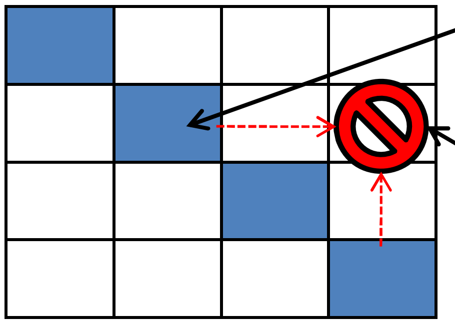
Role of case studies

- Invention in solving problems is based mainly on experts' own ability and experience. However there seem to be several rules in inventions.
- Question: "Can we extract and classify these rules in invention so that they can be used to support solving "new but similar" problems in future?"
- Case studies of innovative problem solving in PA provides opportunity to answer this question.
- Initial idea
  - TRIZ/TIPS (Theory of Inventive Problem Solving) to drive process of invention
  - Generic Model Development Environment (QPAC) to materialize solutions as numerical models

Key components in TIPS

Contradiction matrix

Diagonal cells represent different attributes of output, e.g., products, while off-diagonal cells indicate contradictions and conflicts between the attributes



Solutions

List of measures to achieve goals with respect to individual attributes

Principles

List of principles that can be used to resolve contradiction and conflict between competing goals

Procedure for applying TIPS to PA

- Step 1: Define desired improvements in some attributes
- Step 2: Search solutions to achieve goals with respect to individual attribute
- Step 3: Try possible combinations of solutions for individual goal and find contradictions and conflicts in the contradiction matrix
- Step 4: Search principles to resolve contradictions and conflicts
- Step 5: Develop a model by using QPAC and carry out calculations

Case #1: Development of conceptual model for uplift and erosion scenario (Step 1)

- Problem

  Use of conventional source-term model in which single waste package represents nuclide inventory in whole repository results in large peak dose rate when it enters near surface aquifer if flow and chemical conditions are assumed to change abruptly.

  This may not be true but is believed to be conservative.

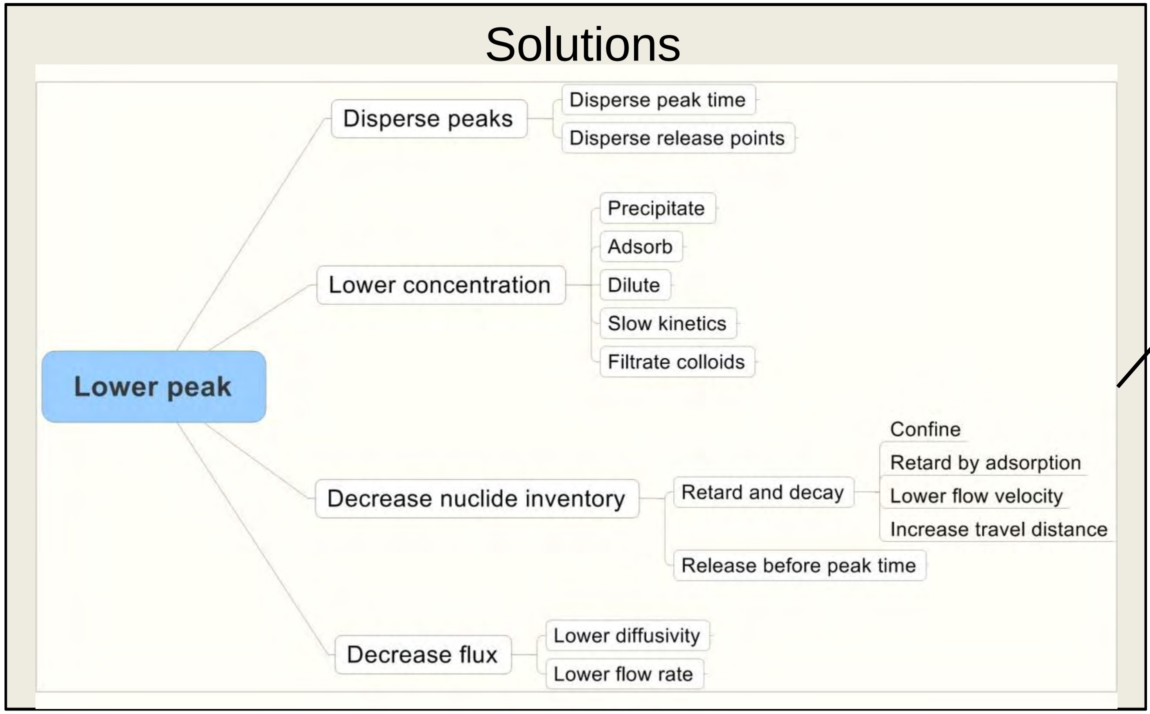
- Desired improvement

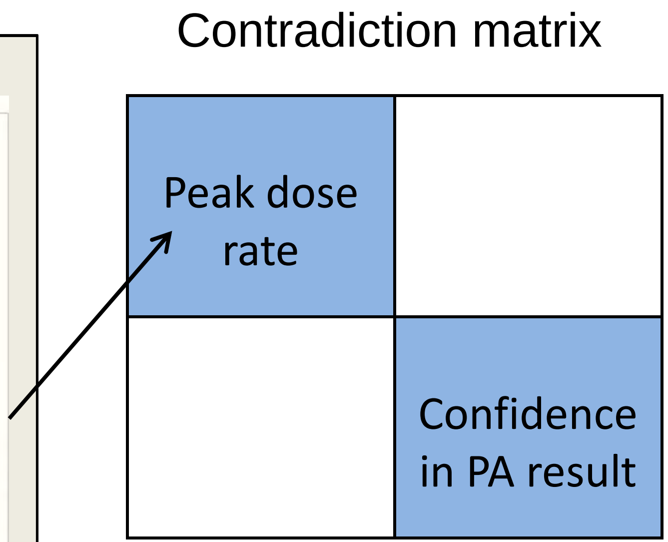
  Lower peak dose rate without compromising confidence in PA result being reasonable upper bound of radiological impact in future

- Attributes
  - Peak dose rate
  - Confidence in PA result

Case #1: Development of conceptual model for uplift and erosion scenario (Step 2)

Search solutions to achieve goals, i.e., lower peak dose rate





Case #1: Development of conceptual model for uplift and erosion scenario (Step 3&4)

- Solution #1
  - Means to lower peak: Disperse peaks in time by modeling many waste packages and changing their time of entry into the near surface aquifer assuming slope of the redox front
  - Conflict: Assumption of inclined bottom of the aquifer is not supported by evidence and not conservative either. Hence the solution compromises confidence in PA result.
  - Resolution of conflict: Varying depth of repository panels and/or individual boreholes guarantees dispersing peaks in time.
  - Principle(?): Diversity in key design parameters, e.g., depth, provides robustness to system's response to "sudden" environmental changes.
- Solution #2
  - Means to lower peak: Increase groundwater flow rate as uplift/erosion progresses so that inventory at the time of entry into aquifer decreases.

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Case #2: Sensitivity analysis for computationally intensive problems (Step 1)

- Problem

  Reactive solute transport modeling for predicting evolution of EBS typically takes several hours for a single case. However significant uncertainties associated with relevant knowledge necessitates carrying out large number of cases.

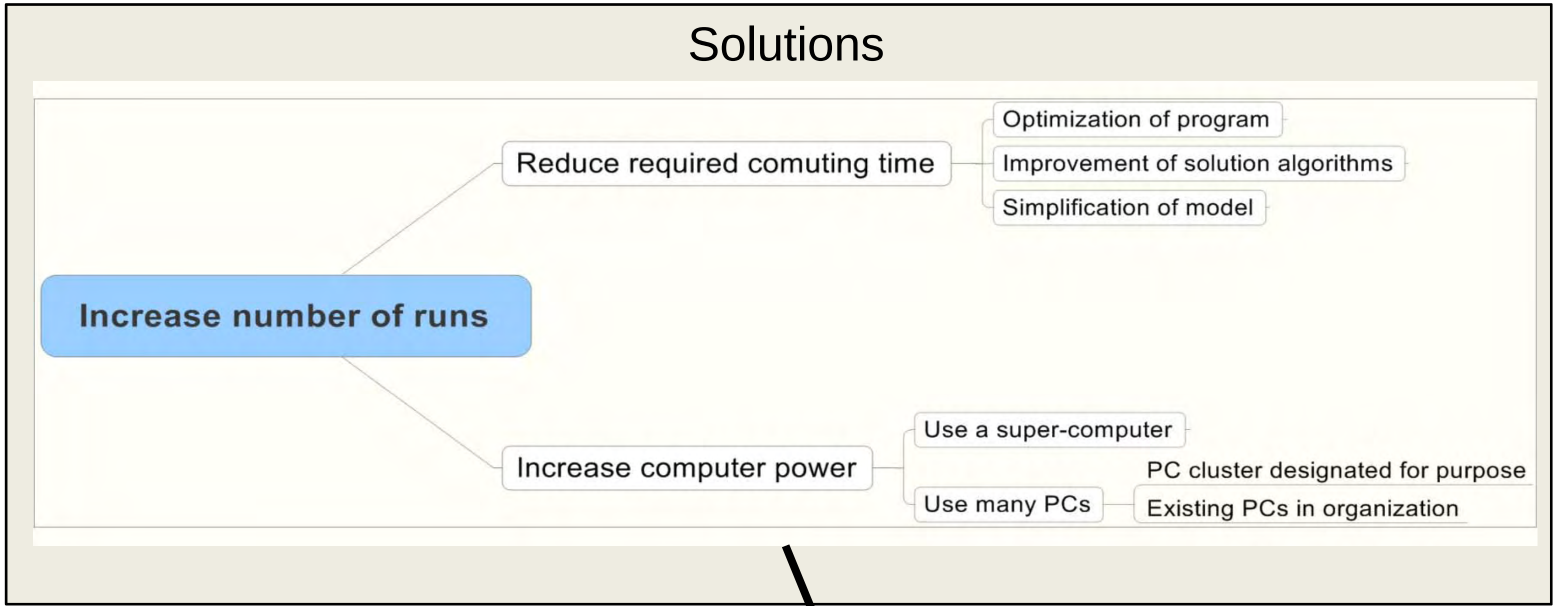
- Desired improvement

  Carrying out large number of runs in practical time scale without excess cost and without introducing significant errors

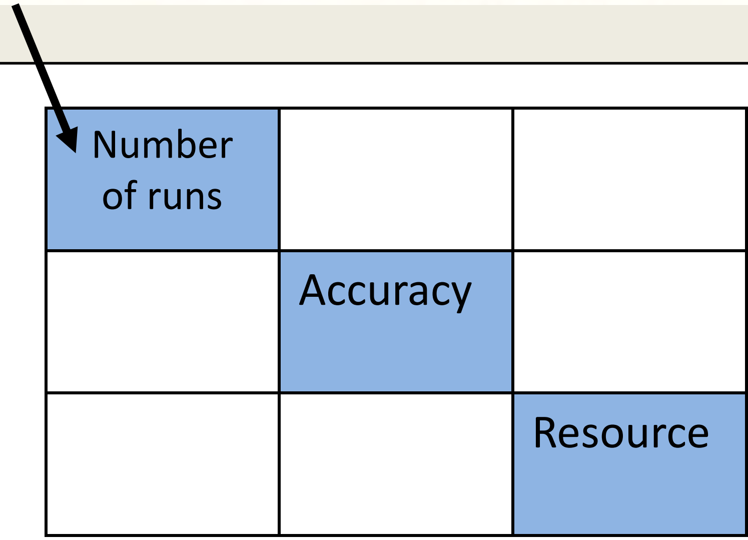
- Attributes
  - Number of runs
  - Accuracy
  - Resources

Case #2: Sensitivity analysis for computationally intensive problems (Step 2)

Search solutions to achieve goals, i.e., increase number of runs



Contradiction matrix

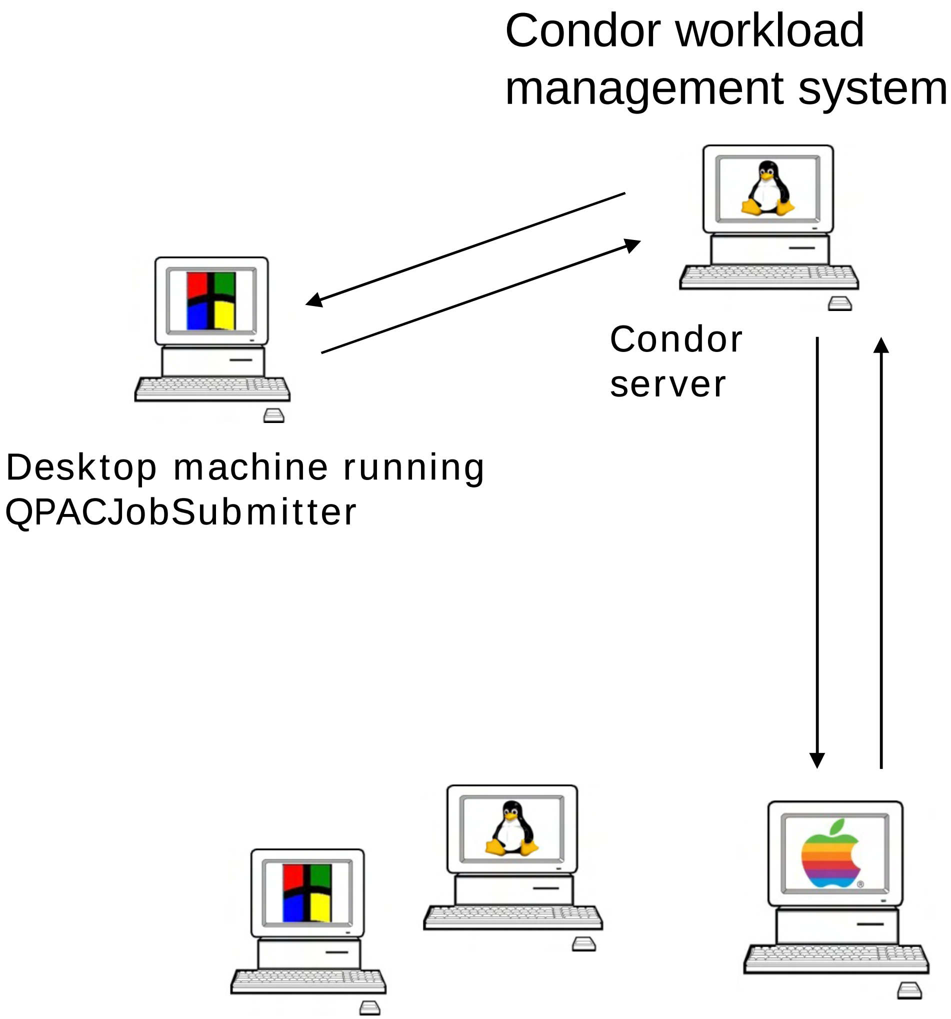


Case #2: Sensitivity analysis for computationally intensive problems (Step 3&4)

- Solution #1
  - Means to increase number of runs: Simplify reactive solute transport model to reduce computing time
  - Conflict: Simplification of highly nonlinear system leads to loss of accuracy
  - Resolution of conflict: Use neural network to capture responses of the original model
  - Conflict: Production of sufficient number of results by the original model for neural network to learn requires time and/or excess cost.
  - Abandoned
- Solution #2
  - Means to increase number of runs : Use many PCs
  - Conflict: Excess cost for purchasing new PCs
  - Resolution of conflict: Use existing PCs in organization
  - Conflict: Most of existing PCs are already in use
  - Resolution of conflict: Allocate computing tasks only when a PC is not used by its owner (Grid computing using redundant machines)

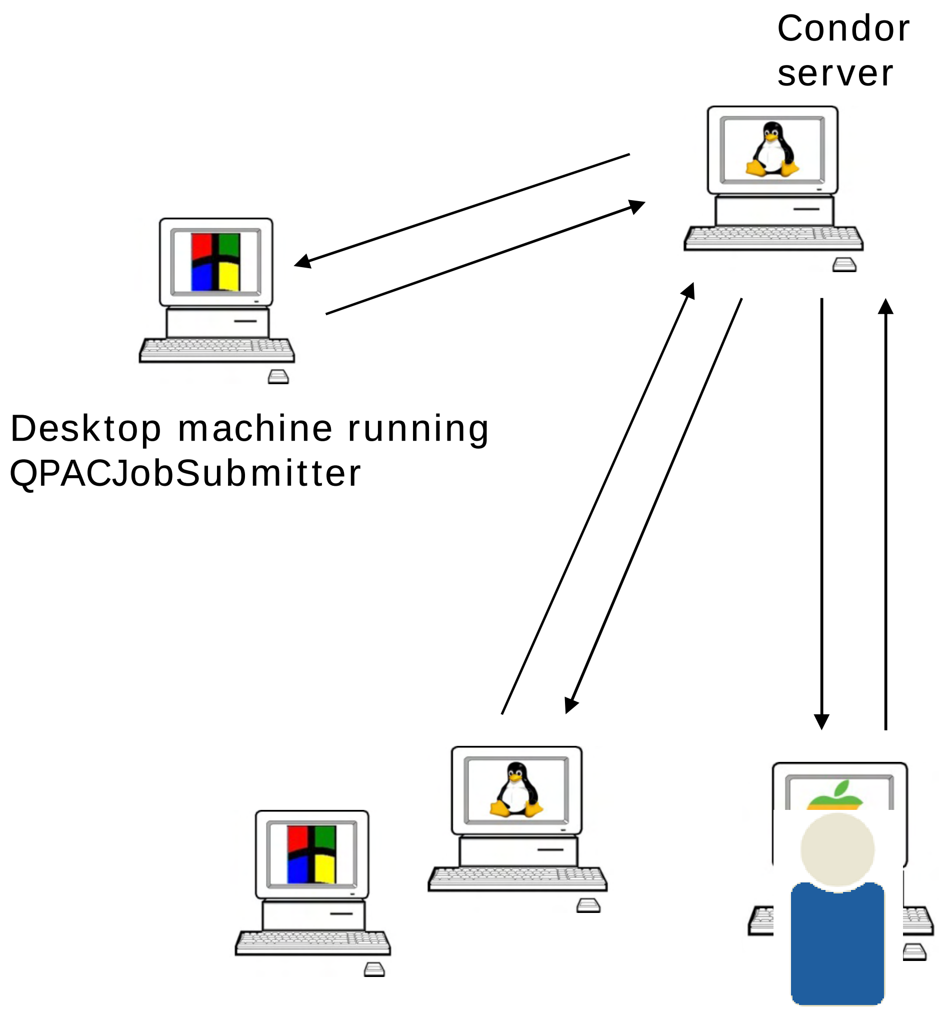
Example of solution #2: QPAC Job Submitter (1/2)

- The QPAC Job Submitter (QJS) is a GUI application
- QJS submits a job, usually a ***collection of jobs***, to a central (Condor) server
- The Condor server manages the task of farming the job across the network
  - Only to machines that have "opted in"
- When the job is completed, the output is returned to the caller

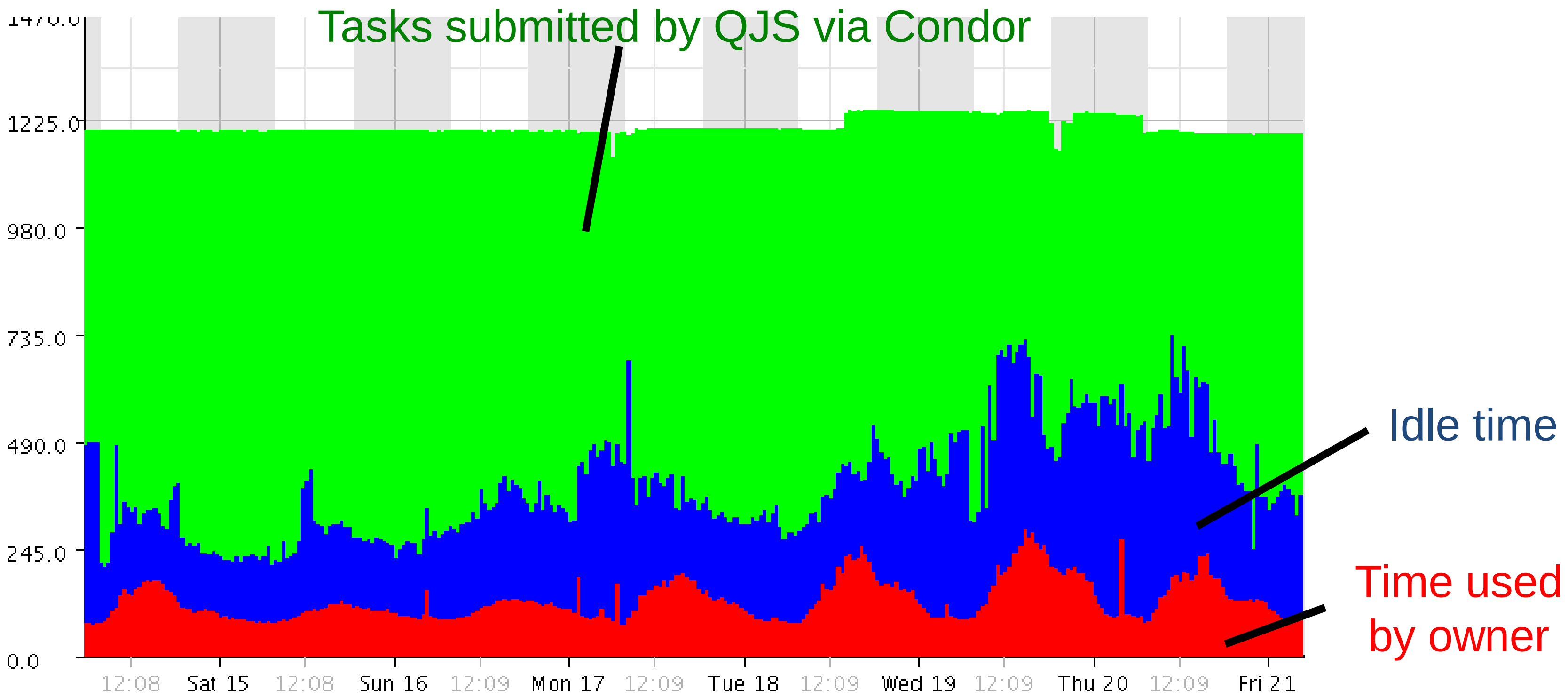


Example of solution #2: QPAC Job Submitter (2/2)

- If the machine running the job becomes busy, the job is terminated.
- Progress so far is passed back to the Condor server.
- The Condor server then identifies another machine that can continue the job
- When completed, output is returned to the caller



Typical usage graph of a PC in the network



Conclusion and way forward

- Two different areas in PA that require distinctive KE approaches are highlighted.
- For a relatively standard PA tasks, a range of IT techniques and tools are applicable. As an example application, All-in-one-report is prototyped to illustrate the idea.
- For inventive problem solving, case studies are attempted to explore possibility of formulating this difficult challenge in a KE compatible manner rather than designing tools straight away.
- In the next phase, case studies with active participation of potential users will be attempted to clarify goals and scope of the system to be developed in a few years time scale.

Presentation context

The JAEA KMS

- **Why and what?** — **Umeki**
- How and when? — Hioki

} PA as an example of a key application

Note that, although there are certainly overlaps, the content of this presentation differs from that given on Tuesday

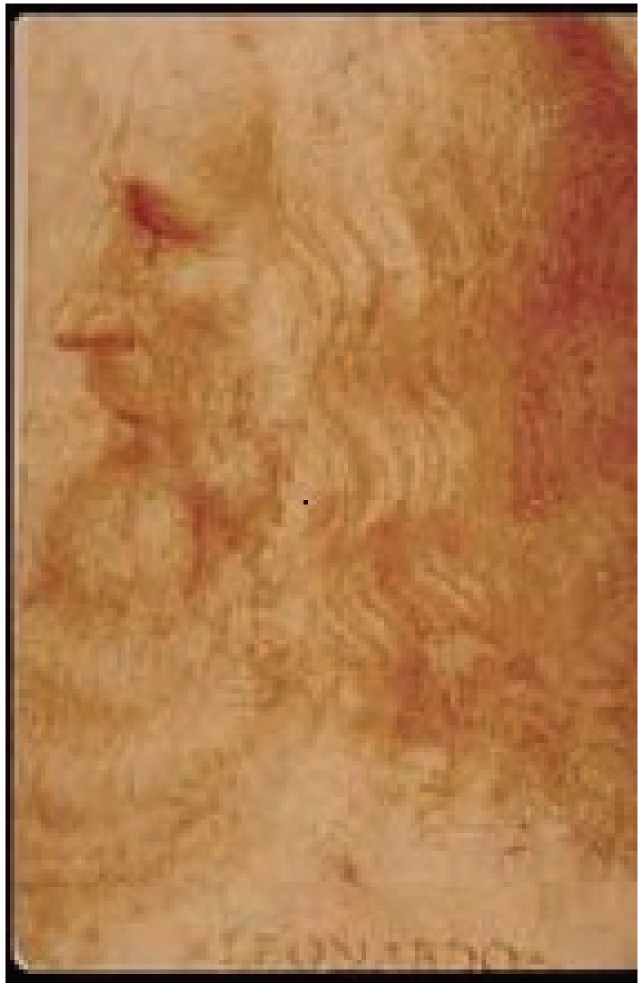
Principle from Knowledge Engineering / Safety Case development – key conclusions should be supported by multiple lines of argument

Possible "lines of argument" to support advanced KMS

- Direct application to Repository Safety Case (including design, siting, PA, ...)
- "Project analogues" – comparison with experience in other industries
  - Failure story of the application ES in the past; e.g. rock mechanics area
    - → key Lessons Learnt
  - More supportive, good "analogues" in other sectors / industries?
- Others?

Why worry about knowledge management?

- Until the time of the Renaissance, it was possible for a genius to master all major areas of the arts and sciences (e.g. da Vinci)
- With the exponential explosion of knowledge in the 19th & 20th centuries, it became impossible for an individual to master all aspects of even a single scientific discipline
- By the end of the 20th century, mastering even a sub-discipline became extremely difficult and the integration of multi-disciplinary projects was acknowledged to be a major problem
- As exponential knowledge growth continues during the 21st century, **the ability to manage information may be the most critical aspect of many projects**



A special concern - tacit knowledge

- Most KM applications noted above focus on **explicit** knowledge - that which can be readily documented
- Just as important is **tacit** knowledge - information and experience which is contained in the heads of senior staff and plays a key role in planning and decision making - **particularly in pragmatic areas of multidisciplinary projects**
- Tacit knowledge has tended to be managed in the past via training / apprenticeships / on-the-job experience transfer, but this is now critical in many programmes due to retirement of staff who played unique development roles
- Special training and mentoring projects may be valuable, combined with more speculative, novel approaches (e.g. based on e-learning supported by expert systems)

Practical implementation

- **Principles are fine, but tricky to carry out in a transparent manner**
- **Formalisation of processes and, in particular, the decision-making procedure can explain and allow consensus on the inevitable trade-offs required to develop a programme that balances competing requirements**
- **General approaches to solution of such problems are known – but few are as complex and multi-dimensional (multi-disciplinary) as radwaste disposal!**

Comments on the Development of KMS and Advanced Performance Assessment
(Private views)

14 November 2008

Katsuhiko Ishiguro

Nuclear Waste Management Organization of Japan (NUMO)

How can NUMO utilize KMS/Knowledge base?

– NUMO is developing the requirement management system (RMS).
– This system can record the requirements and related information for building the repository concepts (or for the preparation of safety case)
– To fulfill the requirements, NUMO needs various arguments and evidences based on the scientific/engineering knowledge.
– If the knowledge is managed with well-organized structure properly, NUMO can compile the necessary information more easily and more efficiently using JAEA KMS.

“Knowledge base” by JAEA would be resource of the fundamental information for NUMO’s RMS.

Comments on the KMS/KB

- **The usefulness of "communication interface" is important for users like NUMO.**
- **Easy, Simple and Flexible system is preferable for users ⇒ Discussion and communication with users important**
- **Well control of the quality/credibility of the system is considered to be still open issue.**

⇒ The KMS will be very useful knowledge base for NUMO's repository concept development. But more information exchange and discussion with expected users are needed in the future.

Requirements: PA & process models (1)

Short term:

- **Process models to allow options for a specific site to be compared**
- **PA models which can distinguish key differences between options (site-specifically)**
- **Qualitative assessment of practicality of construction and operational safety**

(Presented at OECD/NEA EBS-3 Workshop, La Coruna, 2005)

Requirements: PA & process models (2)

Long term:

- **Process models to allow options for a specific site to be optimized**
- **PA models which can quantify key differences between options (site-specifically)**
- **Rigorous, quantitative analysis of practicality of construction and operational safety**

(Presented at OECD/NEA EBS-3 Workshop, La Coruna, 2005)

Next generation PA/process models

- **Long term aims specified in terms of total system perspective**
- **Focus for potential developments in terms of wish lists for treatment of**
  - **EBS**
  - **Geosphere & Biosphere**
- **Further work will be iterated between users and potential developers**
- **Emphasis on long development times: high priority to start very soon**

(Presented at OECD/NEA EBS-3 Workshop, La Coruna, 2005)

Tentative Wish list: Near Field (1)

Based on outcomes of NUMO/Nagra joint project

Stage	End Literature survey	End Preliminary Investigation	End Detailed Investigation
Source term	Constant CR, const SA "Sol Limits"	Mechanistic model	Glass leaching model, surface model, transport resistance
Overpack	1 000 y lifetime	Expected lifetime	Failure distribution Transport resistance
Bentonite	Diffusive RN transport	Diffusive RN transport	Diffusive RN transport (validated)
NF / FF interface	Mixing tank	Basic EDZ	Detailed EDZ
Interaction between waste packages	???	Yes	Yes (validated)
T-H-M-C coupling	No	Partial	Partial (validated)
Perturbations explicitly considered	No		Canister corrosion products
Time evolution considered	No		Yes

(Presented at OECD/NEA EBS-3 Workshop, La Coruna, 2005)

Tentative Wish list: Near Field (2)

Based on outcomes of NUMO/Nagra joint project

Stage	End Literature survey	End Preliminary Investigation	End Detailed Investigation
Saline effects	Effects on parameter values		? Defined saline processes
Thermal effects		Bentonite, retardation	Bentonite, retardation
Gas		Self-healing of bentonite	
Concrete liner	High-permeability model	Degradation Tunnel convergence Bentonite interaction	Detailed high-permeability model
Concrete plug	High-permeability model	Degradation Tunnel convergence	Detailed high-permeability model
Cement grout	None	Rock interaction?	Rock interaction
…..	…..	…..	…..
…..	…..	…..	…..

(Presented at OECD/NEA EBS-3 Workshop, La Coruna, 2005)

What can the regulators expect the JAEA KMS in terms of PA? (Personal views)

S. Masuda (NSC) / H. Kawakami (JNES)

- Review of documents provided for licensing application
  - ➢ The concepts of “all-in-one report” and “coolrep” linked with KB is useful not only for the implementer BUT also for the regulators for their review by increase of :
    - Traceability/transparency
    - Accessibility to key supporting information
    - Improving communication with the applicant
    - QA
- Linkage with knowledge relevant to safety regulations
  - ➢ international guidelines and regulations in other national programmes → to check the consistency with international consensus and trends
  - ➢ past licensing process → to check consistency with past licensing decision (need for clear implication if there is some differences)
- Need for a transparent approach to ensure objective and neutral database as this is a key for the regulators