# Summary record of the topical session of 8th Meeting of the IGSC

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*Handling of FEPs in the Safety Case: Recent Progress and New Methods*

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## Item 11 FEPs Topical Session

### *11.1 Introduction*

J. Alonso, Chair, introduced the topic by recalling that numerous IGSC activities have examined the use and development of FEPs identification and analysis, including 1999 workshop and various aspects of IPAG. The IGSC have seen the evolution of the earliest analyses through the development of systematic FEPs identification and screening to development of an international database of FEPs (now recently updated). This update and other important progress and trends in national programmes will be addressed in the topical session, as well as consideration of further work and priorities in this area.

### *11.2 National experience and practical application of methods for handling FEPs in the safety case*

11.2(a) Andra: "Treatment of Features, Events and Processes in the Safety Case for Dossier Argile 2005"[1]

S. Voinis described Andra's treatment of scenarios in the Dossier 2005. Andra has adopted an iterative approach based on "functional analysis" (FA/AF) and "phenomenological analysis of repository systems" (PARS) to build a qualitative safety analysis (QSA/AQS), in which there is a systematic analysis of uncertainties on FEPs and their effect on safety functions. The QSA is a method for verifying that all uncertainties, in particular related to FEPs and design options, have been appropriately handled in previous steps of the analysis, thereby justifying *post hoc*, e.g., the selection of altered evolution scenarios. It also led to the identification of a few additional calculation cases and has, in principle, the potential to inform design decisions and the derivation of additional scenarios. Once of the objectives is to identify whether the uncertainties are correctly covered by the normal evolution scenario, either in its reference version or in the sensitivity studies considered. If some of the uncertainties are not, it must be confirmed that they would have little impact on the repository or that they refer to very unlikely situations.

1 All presentations are available in full on the dedicated web site for the IGSC-8 meeting.

Based on these, a normal evolution scenario is defined (along with its uncertainties), as well as key altered evolution scenarios that could affect safety functions. The altered scenarios were defined in principle based on feedback from Andra's experience, analysis of situations taken into account internationally, and the recommendations of basic safety rule RFS III.2.f. Through the QSA, it was possible to ensure that the identified altered evolution scenarios covered all significant situations. "What-if" scenarios are also analysed to test robustness. Additionally, Andra used the NEA FEPs database, and other selected sources of information, as a completeness check to ensure that all relevant FEPs were covered by the QSA.

In response to questions following the presentation, Ms. Voinis emphasized that a good understanding of the uncertainties (and the limits of knowledge) concerning FEPs is essential in assessing the significance of their impacts. As far as the programme is progressing, the level of uncertainties is decreasing.

For safety functions, Ms. Voinis noted that functional indicators have been assigned to define acceptable levels of performance for different safety functions. However, these are not numerical values. As there is further optimization of some design aspects (for EBS, for example), the key point is to be aware of how design changes or optimization decisions affect trade-offs among different safety functions.

### 11.2(b) Nagra: "Handling of FEPs in the Safety Case: Nagra's Approach in Project *Entsorgungsnachweis*"

J. Schneider described Nagra's handling of FEPs in the safety case for project *Entsorgungsnachweis*. The approach emphasizes the need to develop a comprehensive scientific understanding of the site characteristics and evolution, and to acknowledge that this can require different approaches than those aimed at providing the data to fulfill modeling needs. Based on basic scientific understanding of the site, key safety-relevant phenomena are identified (for expected evolution and for possible deviations). From the modeling perspective, "super-FEPs" are derived—based on scenario uncertainties, conceptual uncertainties, and parameter uncertainties—describing the reference case for expected evolution and key alternative assessment cases. The safety-relevant phenomena are mapped against the Super-FEPs to ensure that scientific understanding is well represented and, conversely, that modeling assumptions are well-supported. In essence, scenarios are defined as a result of detailed descriptions of the expected repository evolution and alternative evolutions; FEPs lists are used as a completeness check, but not as a primary tool for building scenarios. This approach has advantages of being transparent and also allowing consideration of interactions among FEPs.

In response to questions following the presentation, Mr. Schneider clarified the terminology "reserve FEPs" used in the Nagra programme: a reserve FEP is a FEP that was conservatively left out of the analysis but which, if included, would be expected to add to the margin of safety. The question was raised how timescales were handled, since the Swiss regulatory structure does not establish an outside limit on the timescales to be addressed. In the current iteration of the safety case, Nagra argued that the rough time scale that should be addressed through detailed safety assessment was 1 million years, based on several considerations. For longer timeframes, Nagra argued that there would be no drastic changes or events after 1 million years.

### 11.2(c) SKB: "Handling of FEPs in SR-Can"

A. Hedin described the SKB's approach to FEPs analysis in the SR-Can safety assessment developed to provide feedback for design development and site investigations (SR-Can is not formally part of any license application). For SR-Can, a catalogue of FEPs was identified based on results of earlier assessments and the contents of the NEA FEP database. The handling of the identified FEPs in SR-CAN was established in a series of detailed technical reports covering the following main categories: initial state FEPs, internal processes (e.g., fuel and canister, buffer and backfill, geosphere, biosphere), and external processes (i.e., climate change and future human actions). A "reference evolution" was constructed and analysed in four time frames to assess isolation and radiological releases. A key underlying basis for the performance assessment is the definition of safety functions. The reference evolution is evaluated in terms of safety function indicators in four time frames. The reference evolution is the basis for the definition of a comprehensive main scenario. Furthermore, the identification of additional scenarios for analysis is based on postulated loss of safety functions. The analyses of these scenarios consist of identifying all possible routes to loss of the safety function in question, considering uncertainties not addressed in the main scenario, and assessing whether these situations could actually occur. The consequences of some scenarios that are considered to have a negligible chance of occurrence may still be analyzed for illustrative purposes.

Following the presentation, there was further discussion of the SKB approach of analyzing scenarios that are deemed not plausible to occur. A. Hedin emphasized that the analysis of such scenarios is not seen as undermining the assessment of the FEPs (or the FEPs probabilities) – that is, just because they analyze it doesn't mean they don't believe their own assessment of its improbability. Rather, such an analysis is intended to provide insights into the safety functions, and to be able to produce bounding calculations, much like the "what-if" cases considered by Nagra to show system robustness.

### 11.2(d) US-DOE: "Feature, Event, and Process Analysis for the Yucca Mountain Project Total System Performance Assessment"

A. Van Luik described the US-DOE approach to FEPs analysis in the safety case for Yucca Mountain. To start the process, US-DOE first incorporates the regulatory basis and guidance set forth by the U.S. Nuclear Regulatory Commission. Within this context, through an iterative process over the course of several years, US-DOE compiled an initial FEPs list (over 1500 items) based on numerous sources, including the NEA FEPs database, site-specific FEPs from Yucca Mountain-related studies, and independent internal and external reviews. These FEPs were grouped into several hundred "primary" FEPs which were then screened based on regulatory criteria, probability, and consequence. All FEPs identification and screening decisions are documented in an extensive electronic database with links to technical reports and other information supporting the source for the information and the ultimate decisions. A key element in the identification and evaluation process is good coordination among the various technical disciplines and organizational elements to ensure completeness and accuracy.

The FEPs collectively capture all the issues relevant to post-closure performance of the proposed repository. The FEPs are compiled into scenarios which are used to construct three major classes: nominal (expected) evolution, igneous disruption, and seismic disruption. Human intrusion is analysed separately, in a stylized scenario prescribed by regulation. To close the presentation, A. VanLuik emphasized that FEPs screening is an iterative process. The arguments and bases for FEPs identification and screening have continued to mature in recent years, especially in preparation for a license application expected by US-DOE in the next year. FEPs screening is reviewed as part of any activity that may lead to model changes, and new FEPs can be added if they are identified.

### 11.2(e) ASN: "Features, Events, Processes: A Regulatory Approach"

P. Bodénez provided insight into the views of a regulator on the FEPs analysis process, from the perspective of the French programme and a review of Andra's scenario analysis in Dossier 2005. He noted that French regulations define basic safety requirements for the reference scenario as well as consideration of other hypothetical events that could affect the migration of radionuclides to the biosphere, including changes to the geological system; defects in engineered components, natural events, and human induced events. Representative scenarios should be modeled to account for possible consequences of events that are deemed likely to be able to occur.

Based on these requirements and on the consideration of safety functions, Andra defined three main scenarios outside the nominal performance: seal failure, package/overpack failure, and drilling. A "very degraded" scenario (i.e., combined defects of seals, containers, and packages, plus lower-than-expected clay permeability) was also analyzed for informational purposes. He noted that the analysis provides information on key sensitivities for performance; however, even the very degraded scenario in the Dossier 2005 showed potential doses below the regulatory limits for 10,000 years. In general, the methodology used by Andra in the recent safety case was found to be comprehensive, although there is further discussion of some specific decisions and regarding conclusions for several "what-if" scenarios. Finally, he emphasized that the regulations require a comparison to acceptability criteria, but the regulatory review ultimately is concerned with whether the implementer demonstrates a comprehensive understanding of the system and the phenomena that may affect it.

In discussion following the presentation, P. Bodénez reiterated the importance of a comprehensive and logical methodology for scenario analysis, and noted positively the work Andra had done in this regard for the Dossier 2005, particular the definition of safety functions. In response to a question, he clarified that there is a regulatory dose limit of 0.25 mSv/year applied for the first 10 000 years after repository closure; potential doses beyond that time must still be analysed, but there is not a dose limit in regulations. The rule is in the process of being revised, and changes may be possible.

### *11.3 FEP Database Update*

11.3(a) Status of the Database

T. Sumerling provided a presentation and demonstration of the updated NEA International FEPs Database. He reminded meeting participants that the first version of the database was released by NEA in 2000. Version 2 is now complete.

Certain key features remain the same from the first database, including:

- The International FEP list and the principle of mapping project FEPs to the International FEPs
- The basic structure, appearance, and functions
- All the previously available project information is still included (just some clarifications in the project descriptions in the database).

Version 2 also provides some important updates and improvements:

- In terms of content:
    - 2 project databases have been added: SCK-CEN FEPs for the Mol site (1994), Encyclopedia of Swedish SFR FEPs (2002)
    - The database now covers over 1650 project FEPs and many literature references
    - More detailed information is given concerning each of the included projects
- In terms of function:
    - As agreed at the last IGSC meeting, restrictions on printing and review of underlying data are removed
    - The database is compiled to run as a Windows application and can run simultaneously with other applications.
    - Improvements were made in print capabilities and screen appearance

**The final version will be placed on CD-ROM, and should be available shortly.** The CD-ROM will include the “runtime” application. The underlying Filemaker data files are recommended not to be included on the CD-ROM, since this could allow the data to be manipulated in ways that we cannot control (i.e. someone could make something that looks just like the NEA database but has different/changed data). These files, however, will be provided to NEA and also to the funding organizations.

T. Sumerling provided a short demonstration of the program, including the background and user information; instructions for use; summary of differences from the previous version; additional notes and troubleshooting. In conclusion, he acknowledged that the database platform is several years old, and may not offer all the flexibilities desired; nevertheless, there are more flexibilities and functions that people can now take advantage of, and we should remember that it has been used productively by a number of programmes to support their safety cases.

11.3(b) FEPs Survey Results

B. Forinash presented the results of an informal survey on FEPs database usage and information needs in national programmes. In response to a short survey from the Secretariat, input on these issues was provided from 10 different organizations representing seven countries. Generally, the results showed that the usage of the database in practice meets well the original goals of the project; a number of programmes have used the database as a starting point to generate site-specific FEPs lists and as a check or cross-reference for their own work and FEPs lists. It is viewed as helpful for building transparency, and also as a useful tool for regulatory review. National programmes also rely on other information sources, especially site-specific data.

As programmes move toward more developed safety assessments, there is greater demand for more detailed information on FEPs screening and analysis. The NEA FEPs database has some limitations in this regard, because the level of detail in the database information is variable (reflecting the underlying documentation) and also because of the necessary lag time in incorporating new published results into the database. It was emphasized, however, that it is valuable to ensure that the database remains readily accessible---even if it is not updated further---to allow its continued use by regulators and by programmes at earlier stages of development.

According to the survey results, possible areas for further work regarding scenario analysis might include:

- Information on screening and classification
- Links between FEPs and modeling
- In-depth exchange on FEPs for specific media or disposal system components.

In general, it is viewed that IGSC can be an effective avenue for such coordination and information exchange through, for example, an updated and more flexible database concept (with detailed indexing and links), specialized projects, and working groups.

## *11.4 Topical Session Discussion/Round-Up*

J. Alonso summarized the Topical Session by noting that the information presented has shown the most recent progress on the treatment of FEPs. In all cases, there is an emphasis on good scientific understanding of the system as a starting point for building the safety case. In addition, all programmes strive for clarity and transparency in their safety case, and this is an important driving force in the development of methods and analysis for FEPs.

The U.S. approach based largely on the FEPs database has remained relatively constant, and is particularly suited to the YM case. In the European cases, there are some different approaches being reflected – in particular, the aspect of safety function analysis for the definition and selection of scenarios, and identifying which issues really challenge the safety case. For these, the FEPs list does not play as central a role, but is still used as a confirmatory tool in terms of completeness of FEPs considered. The use of “what-if” scenarios also appears to be becoming more common, although the limitations and complications of such cases are acknowledged. Another aspect of interest is the greater emphasis in several programmes on systematic analysis of uncertainties to inform FEPs identification and screening.

In the subsequent discussions, several IGSC members noted that the NEA FEPs database has been instrumental for many national programs as a starting point in developing national FEPs lists or scenarios and as a confirmatory check on such lists. The advancement of program-specific FEPs databases has perhaps eclipsed the need to foster further development of the NEA FEPs database. Some programmes might expect to revisit the database even if they have already used it, but this would be most useful only if it is kept very up to date---and it was noted that this is a continuing challenge since there is a necessary lag time in incorporating recent published results. There was some interest in the possibility of developing a modernized database concept which could be indexed and easily updated to provide links and "pointers" to new information from various national programmes. This also might provide an avenue to link FEPs more clearly to scenarios (or vice-versa, depending on the approaches used in national programmes).

There was some discussion that apparent differences in approaches to scenario analysis may not be so great in reality, but rather reflect differences in terminology. For example, DOE does not undertake a process labeled "functional analysis," yet the consequences and significance of FEPs are assessed by examining the functional performance of various barriers. Conversely, not everyone defines and uses "safety functions" in the same way. It is important to look beyond the terminology and the descriptions of the process to see what is really done in practice. In a similar vein, a question was raised regarding the conceptual differences (if any) in the various FEPs listed in the NEA database – do the over 1500 FEPs really represent different processes, or just different terminology?

**In conclusion, the FEPs database was endorsed as a useful tool, and the recent updates are commended. Given the progress of national FEPs lists and the challenges of keeping the database current, there was consensus that a concerted effort was no longer needed for further updates, but at the same time it is important to maintain the existing version and make sure it remains accessible. A comprehensive view should be taken in establishing priorities for future information exchange on scenario analysis, perhaps building or expanding on the concept of the existing database, and with a view to using tools that might be more readily updated to keep pace with new information.**