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A Formal Process for Elicitation and Validation of Expert Judgments for Safety Case in the Context of Spent Nuclear Fuel Management

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September 2008

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A FORMAL PROCESS FOR ELICITATION AND VALIDATION OF EXPERT JUDGMENTS FOR SAFETY CASE IN THE CONTEXT OF SPENT NUCLEAR FUEL MANAGEMENT

ABSTRACT

The report introduces a proposal for a formal expert judgment elicitation and validation process for Posiva in the construction of the safety case of the spent fuel disposal facility at Olkiluoto. The procedure has been developed by adopting a systemic, interaction-based approach to elicitation and validation. By taking this view the approach differs from other approaches to formal expert judgment.

The concept for the formal procedure has been developed by taking the support for collaboration as the primary requirement for the development. The procedure provides systematic practices and a forum for joint assessment and makes it possible for the domain experts to participate in the discussions and decisions on the validity of the input data. In addition to the experts, also the safety analysts are elicited, in a way. The two-way elicitation enhances mutual understanding between the participants and assures collaboration of equal parties.

The procedure provides also conceptual tools that support decision making in validation by enhancing transparency of reasoning. The predefined forms and descriptions serve as shared frames of references and enhance the comprehension of, e.g., the nature and impact of the uncertainties of the input data, the ways of thinking underlying the different disciplines and the significance of one's role as part of the construction of the safety case.

Enhanced motivation and transparency of reasoning contribute to improved transfer and integration of knowledge across the disciplinary boundaries and, as a consequence, makes it easier to reach a consensus between the participants.

Keywords: safety case, safety analysis, expert judgment, expert elicitation, validation of expert judgment, collaboration, cross-disciplinary, transparency, systemic approach, conceptual tools

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MENETTELYTAPA KÄYTETYN YDINPOLTTOAINEEN LOPPUSIJOITUKSEN TURVALLISUUSPERUSTELUN ASIANTUNTIJA-ARVIOIDEN TUOTTAMIS- JA PÄTEVÖINTIPROSESSILLE

TIIVISTELMÄ

Raportissa esitetään ehdotus asiantuntija-arvioiden tuottamis- ja pätevöimisprosessista, jota voidaan käyttää Posivassa käytetyn polttoaineen loppusijoitusta Olkiluodossa koskevan turvallisuuperustelun rakentamisessa. Menettelytapa perustuu vuorovaikutusta painottavaan systeemiseen lähestymistapaan, joka eroaa lähtökohdiltaan muista lähestymistavoista asiantuntija-arviointiin.

Menettelytavan konsepti on kehitetty ottamalla ensisijaiseksi vaatimukseksi prosessin antama tuki osallistuvien osapuolten yhteistyölle. Menettelytapa tarjoaa systemaattiset käytännöt ja foorumin yhteistyönä tapahtuvalle arvioiden muodostamiselle ja mahdollistaa substanssialojen asiantuntijoiden osallistumisen lähtötietojen validiteettia koskeviin keskusteluihin ja päätöksiin. Myös turvallisuusanalyytikoiden päättely arvioiden muodostamisessa on omalla tavallaan tarkastelun kohteena. Kaksisuuntainen tarkastelu lisää osapuolten keskinäistä ymmärrystä ja varmistaa tasa-arvoisen yhteistyön.

Menettelytapa tarjoaa myös käsitteelliset työkalut, jotka tukevat validointia koskevaa päätöksentekoa lisäämällä päättelyn läpinäkyvyyttä. Ennalta suunnitellut lomakkeet ja kuvaukset toimivat yhteisinä kehyksinä ja lisäävät ymmärrystä esim. lähtötietoihin liittyvien epävarmuuksien luonteesta ja vaikutuksista, eri alojen ajattelutavoista ja oman roolin merkityksestä osana turvallisuusperustelun rakentamista.

Lisääntynyt motivaatio ja päättelyn läpinäkyvyys parantavat tiedon välittymistä ja integrointia eri alojen rajapinnoissa, minkä seurauksena yhteisymmärryksen saavuttaminen on helpompaa.

Avainsanat: turvallisuusperustelu, turvallisuusanalyysi, asiantuntija-arviointi, asiantuntija-arvioiden tuottaminen, asiantuntija-arvioiden pätevöittäminen, yhteistyö, poikkitieteellinen, läpinäkyvyys, systeeminen lähestymistapa, käsitteelliset välineet

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1 INTRODUCTION

To date, Posiva's plans for the long-term safety case of geologic disposal of spent fuel have been based on the Safety Case Plan proposed by Vieno and Ikonen (2005). Following the recommendation from the Finnish Authority for Radiation and Nuclear Safety (STUK), Posiva is now in the process of updating this plan (Posiva 2008). In particular, the purpose of the revised plan is to provide more information on certain methodological aspects of the safety case that STUK considers too vague in the present plan. Among them is the call for more comprehensive plan for the quality management.

The current plan for the quality management of the safety case activities is to adopt a graded approach. This means adopting the level of quality assurance measures according to the importance of the activity for the long-term safety assessment. In order to make it possible to assess how the data and assumptions are used in the safety assessment, descriptions of the whole chain of activities to produce the input are produced for safety-critical assessment data and parameters that influence the safety analysis directly. The chain of activities to produce the input is controlled and described in the Models and Data reports. The descriptions are made for the critical design and implementation data and for the critical site data. For example, the planned quality management process for the production of the critical site data are:

- Assignment/identification of duties and responsibilities,
- Identification of critical site data,
- Identification of the production lines,
- Control of the production processes along the chain of activities to produce the input,
- Clearance (verification and validation for use),
- Documentation, and
- Improvement.

As part of the quality management for the construction of the safety case a formalized expert elicitation process will be applied to safety-critical judgments presented in the data reports. The person responsible for the quality management, the Safety Case Quality Manager, will be the owner of the elicitation and validation process. The purpose of this report is to give guidance and a practical framework for that process.

According to NEA's guidance (NEA2004) expert judgment is needed in particular for

- conflicting data sources,
- data collected using laboratory scale experiments where the uncertainty is on a field scale,
- unverified models or measuring procedures,
- analogue chemicals and tracer elements,
- limited evidence, and
- data insufficiency to internally estimate uncertainty.

Formal expert judgment has become a relatively well-established tool for risk assessments in the nuclear field (Simola et al. 2005). It has been used in a more or less

systematic way. Different approaches have been used but uniformity in its use is still lacking.

Generally, the required characteristics of a formal structured elicitation and validation process in the field of nuclear waste are transparency and traceability (e.g., Wilmot & Galson 2000). However, in the development of procedures for elicitation and validation for safety analysis little attention has been paid to the interactive and cross-disciplinary character of the process. For SKB's SR-CAN Report, documentation in the Data report has been made according to a preset protocol (SKB 2006). The experts' and the safety analysts' contributions are strictly separated from each other and the latter ones make the final decisions. Expert panels have not been arranged. At NAGRA, there are no formal rules for conducting the process but cross-audits between the different groups participating in the constructing of the safety case are emphasized (Nagra 2002).

In the field of reactor safety, formal procedures, e.g. those developed at VTT and carried out for risk analysis for the regulator, are intended to support probabilistic risk assessments (e.g. Pulkkinen & Holmberg 1997). The general structure of the procedure is described in an overview report, published by the Institute for Energy of European Commission (Simola et al. 2005). The process requires from the experts not only substance expertise but also the ability to express uncertainty with probabilities. Ideally, the experts should have a solid background in probability theory and statistics. Since this is often hard to achieve, a training session is an important part of the expert judgment process. The experts participating in the process are usually from one substance domain. The cross-disciplinary interaction of the substance experts and the risk analysts has not been given special attention.

An expert panel approach developed at VTT to support risk-informed decision making, aims at achieving a balanced utilization of information and expertise from several disciplines in decision-making including probabilistic safety assessment as one decision criterion. (Pulkkinen & Simola 2000). The role of the panel is to synthesize the views of various experts and identify and characterize the uncertainties in their analyses. "Normative" experts, representing decision analysis, act as facilitators during the panel. A format for group decision making is needed in order to structure the problem and support discussions and documentation of the views. The task of the formats is to present the results of the technical analyses, to identify the most important assumptions and uncertainties of the analyses, and to present explicitly the experts' reasoning and its bases. The documentation and discussion format is case-dependent. The approach has been applied in a pilot study, concerning risk-informed in-service inspection, to combine deterministic and probabilistic information. In the course of the panel sessions the expert judgments were evaluated with an emphasis on identifying uncertainties in different kind of analyses.

The expert panel approach described above provides elements that could be applied in the field of nuclear waste management. There is, however, need for considerations of the elicitation and validation process from the collaboration point of view.

The suggested formal procedure, to be introduced in this report, has been developed by adopting an interaction-based and systemic approach to elicitation and validation. By

taking this view the approach differs from the other approaches to formal expert judgment.

The systemic approach is introduced in chapter 2. The suggested formal procedure for the elicitation and validation process is described in chapter 3. Preparations for implementation of the procedure are discussed in chapter 4 and suggested future developments in chapter 5.

2 SYSTEMIC APPROACH TO ELICITATION AND VALIDATION OF EXPERT JUDGMENTS

The development of the suggested procedure is based on an systemic approach, developed at VTT Systems Research Centre and applied, e.g., to nuclear waste management context in previous studies (Hukki & Pulkkinen 2002, 2003a,b,c, 2004, Hukki & Holmberg 2007). According to the view taken, the elicitation and validation process is regarded as a collaborative and cross-disciplinary whole. The systemic character of the process sets requirements for the formal procedure. The procedure has been deliberately designed to fulfil these requirements by supporting collaboration of the participating disciplines.

The rationale of the concept of the suggested formal procedure is the following.

Structured performance, transparency and traceability are goals for an elicitation and validation process from the quality assurance point of view. If the process is considered from the safety case point of view, the goal is to conduct the process in a way that efficiently produces valid input for safety analysis. The efficiency is dependent on the way of the participants' interaction. Reaching a consensus on the validity of the input data is desirable. It is desirable also in the sense of motivation and trust of individual persons participating in the process. The best way to reach a consensus is to conduct the process on the basis of cooperation. There are, however, challenges concerning collaboration, due to the complexity of the issues to be handled and the cross-disciplinary character of the process.

The expert elicitation and validation process is part of the collaborative construction of the safety case. The process takes place as a result of interaction of different kinds of expertise. The persons who are usually called the experts in formal expert elicitation are representatives of specific substance domains or disciplines. The safety analysts, representing research on long-term safety of disposal of spent nuclear fuel, are sometimes called generalists, since their work requires expertise on safety analysis and a more general type of substance expertise.

The safety analysts and the domain experts contribute to the construction of the safety case in a different way, the former ones directly and the latter ones indirectly. Safety assessment requires transferring and integration of knowledge across the disciplinary boundaries but due to the differences of domain-specific practices, concepts, terminology and ways of thinking there are difficulties in gaining a mutual understanding. The way of thinking underlying the safety analysis is often difficult to experts coming from other substance domains.

The concept for the procedure has been developed by taking support for collaboration as the primary requirement for the formal procedure. In order to fulfill this requirement the procedure should provide

- systematic practices and a forum for joint assessment and
- conceptual tools to support collaboration and documentation.

Systematic practices for collaboration organize the whole elicitation and validation process in a way that enhances mutual understanding and, as a consequence, enhances the experts' motivation and, possibly, the parties' interest in the process. The practice makes it possible for the domain experts to participate systematically in the discussions and decisions on the validity of the input data. Another principle is that in addition to the experts, also the safety analysts are elicited, although in a different way. The two-way elicitation enhances mutual understanding between the participants and provides collaboration of equal parties.

Conceptual tools are predefined forms and descriptions that support collaboration by enhancing an understanding of, e.g., the uncertainties and the impact of the input data, the ways of thinking underlying the different disciplines and the significance of one's role as part of the construction of the safety case. They are intended to enhance transparency and facilitate decision making in validation. The tools are used by both the safety analysts and the experts.

Enhanced motivation and transparency of reasoning are assumed to increase mutual understanding at the cross-disciplinary boundary between the safety analysts and the experts. Improved transfer and integration of knowledge facilitates elicitation and validation and makes it easier to reach a consensus between the participants.

3 PROCEDURE FOR THE FORMAL PROCESS

The suggested procedure for the formal process of eliciting and validating expert judgments is based on the principles described in the previous chapter.

The process is conducted according to a written procedure, a protocol, which provides guidance and serves as the format for the documentation of the conducted course of action. The protocol is included as an element in the documentation of the quality management concerning the construction of the safety case.

3.1 Development of conceptual tools

The purpose of the conceptual tools is to provide the safety analysts and the domain experts with tools that support collaboration in elicitation and validation. There are different types of tools: *Elicitation Forms* for each party and *Structural and Contextual Descriptions* that serve as shared frameworks for both parties. The tools complement each other and as a combination they are intended to support the different aspects of collaboration.

The conceptual tools can be improved and developed further on the basis of accumulating experience from performed elicitation and validation processes. Development requires cross-disciplinary collaboration and should be organized by the Quality Manager.

3.1.1 Elicitation Forms

The purpose of the *Elicitation Forms* is to facilitate elicitation and validation by providing means for making the safety analysts' and the experts' reasoning processes more explicit. The forms are designed before implementing the formal procedure (see chapter 4).

There are two types of forms, one for the safety analysts and one for the domain experts.

Safety Analysts' Elicitation Form

The function of the *Safety Analysts' Elicitation Form* is to support the safety analysts in preparing their preliminary conceptions of the domain expert judgments. The predefined format gives guidance on formulating, justifying and documenting the preliminary assessment of expert input uncertainties in a transparent way. The format also helps making the characteristics and boundary conditions of safety analysis as a methodology as explicit as possible. Enhanced transparency from the safety analysts' side makes it easier for the domain experts to understand the significance of their judgments and the related uncertainties in safety analysis and, as a consequence, in the construction of the safety case.

The format gives guidance on expressing and documenting explicitly the following issues:

Ways of using the expert input in safety analysis:
- what is the intended use of the input?
- what is the predicted or possible impact of the uncertainty, related to the input, on assessment results?

Characteristics of safety analysis affecting the production of the preliminary assessment of the expert input:
- what are the limitations, uncertainties and assumptions concerning the assessment of input data, specific to safety analysis?

The way of thinking underlying the production of the preliminary assessment:
- what are the underlying assumptions and grounds, e.g., experiences in previous assessment cases described in relevant literature?

Difficulties in producing the preliminary assessment:
- what kind of obstacles and difficulties the safety analysts have experienced in producing the assessment?

Subjective uncertainty related to the preliminary assessment:
- what kind of uncertainty is related to the assessment and what kind of factors have caused the uncertainty?
- what is the significance of the uncertainty in safety analysis and in the construction of the safety case?

Experts' Elicitation Form

The function of the *Experts' Elicitation Form* is to support the domain experts in the production of the expert judgments. The guidance and the questions give the experts points of reference for structuring the problem or issue requiring a decision. In addition, the form directs them to express the related subjective uncertainty in the required format and describe and document their reasoning process and their underlying way of thinking.

The questions concern use of knowledge and the logic and the way of thinking in the reasoning process. They can be categorized and expressed in, e.g., the following way:

Ways of producing the judgment:
- for what purpose and how the data are produced?
- for what purpose and how the models are chosen and used?
- how the sub-models are combined?

Characteristics of the expert's domain affecting the production:
- what are the domain-specific or cross-disciplinary limitations, uncertainties and assumptions?

The way of thinking underlying the production of the judgment:

- what are the underlying assumptions and grounds concerning the interpretations, decisions, choices, omissions etc.?

Difficulties in producing the judgment:
- what kind of obstacles and difficulties the expert has experienced, related to, e.g.
  - observations and measurements?
  - interpretations (theory/models)?
  - abstraction (inferences, upscaling)?
  - prioritizations and omissions?

Subjective uncertainty related to the judgment:
- what kind of uncertainty is related to the judgment and what kind of factors have caused it?
- what is the significance of the uncertainty in the domain-specific discussions?
- what is the predicted or possible impact of the uncertainty on the assessment results of the safety analysis?

3.1.2 Structural Descriptions

The *Structural Descriptions* are intended to support the common handling of the issue and comparison of the safety analysts' and the experts' views in a structured way. The descriptions provide shared frames of reference for describing and discussing uncertainties and possible inter-relations of uncertainties. Possible ways of structuring the problem to be handled could be categorization, risk matrixes, evaluation of influencing factors and consequences, etc. Relevant structuring methods developed for the formal expert judgment in the field of reactor safety could possibly be utilized (see, e.g., Pulkkinen & Simola 2000). The descriptions can be presented as, e.g., tables and influence diagrams. Conceptual simulations may be used as well.

The descriptions are designed before implementing the formal procedure (see chapter 4). Relevant descriptions are selected and possibly updated for each elicitation and validation process, according to the issue to be handled.

3.1.3 Contextual Descriptions

The *Contextual Descriptions* support the safety analysts' and the experts' collaboration by providing shared frames of reference that enhance the experts' understanding of the role and significance of the input data in the context of the safety case.

There are different possibilities to describe the safety context of the expert input. One possibility is to present the production of the input data by illustrating the input as a result of a chain of activities concerning production, integration and use of knowledge in forming the concept for the safe solution for the disposal. The descriptions of the chain of activities that will be developed at Posiva for making the way of producing the input explicit represent this type. Another possibility is to present the way of treating the input data in safety analysis. This can be illustrated by, e.g., presenting the characteristic logic and way of reasoning in the analysis. Still another way is to present the use of the input data in the construction of the safety case. The illustration can be made by

presenting the structure and logic of the safety case as a system of constructing evidence and disclose the role of the input in this system.

Presentations of collaboration in the construction of the safety case can be used, too, since they emphasize the interactive character of the construction process. This kind of description is included in the data report of NAGRA (Nagra 2002). The description presents the participation of the different organizational groups in the development of the safety case on a general level.

The *Contextual Descriptions* are developed before implementing the formal procedure (see chapter 4). A flowchart is one example of a suitable form for presenting a description visually. The descriptions are updated for each elicitation and validation process according to the issue to be handled.

3.2 Phases and participants of the process

The process consists of the following phases:

- Selection of issue,
- Selection of forum,
- Selection of experts,
- Selection of shared conceptual frameworks,
- Preparatory work of safety analysts,
- Training of experts,
- Instruction of experts,
- Independent work of experts,
- Iterations,
- Validation of expert judgments for later use,
- Treatment of possible controversies, and
- Final documentation of the process.

The Quality Manager responsible for the process has the leading role in conducting the process. It is important that this person participates in each phase because it makes it possible to gain an understanding of the process as a cooperative whole and of the development needs of the participants' ways of interacting.

The other parties of the process are the safety analysts from Posiva's Safety Case Project's (SAFCA; see Posiva 2008) Core Group and the domain experts, representing fields of expertise that are related to the selected issue. It is proposed that in the case of possible controversies in the validation of the judgments the representatives of the Safety Committee, a permanent Posiva group responsible for reviewing decisions and actions bearing on operational or long-term safety, should also participate in the process. If an expert panel is arranged for eliciting probabilistic judgments, a normative analyst may participate.

The participants in each phase of the process and the degree of their contribution are described in Table 1.

3.3 General procedure

The procedure for each phase of the process is described in the following. The role of the participants in carrying out the activities is presented in table 2.

3.3.1 Selection of issue

The safety analysts take the initiative on elicitation of a safety-critical issue on the grounds of the needs of safety analysis. The Quality Manager of the safety case can also take the initiative, on the basis of the Quality Assurance (QA) review on the reports.

The range of issues can vary from selection of numerical values (or the related probability distributions) for a set of experimental parameters to definition of scenarios concerning glacial periods.

Table 1. *Participation in the elicitation and validation process.**

Phase	Quality Manager	Safety analysts	Domain experts	Safety Committee
Selection of issue	x	X		
Selection of forum	X	X		
Selection of experts	X	x		
Selection of shared conceptual frameworks	X	x	[x]	
Preparatory work of safety analysts	x	X		
Training of experts	x	X	X	
Instruction of experts	x	X	X	
Independent work of experts	x		X	
Iterations	x	x	X	
Validation of expert judgments for later use	x	X	X	
Treatment of possible controversies	x	X	X	X
Final documentation of the process	X			

*) (X = major contribution, x = supportive contribution, [x] = optional supportive contribution)

3.3.2 Selection of forum

The way the process is arranged depends on the selected issue. For some issues input may be available only from few domain experts, while in other cases numbers of experts from different disciplines would be available (Posiva 2006). In the latter case the number of experts ideally needed for the elicitation and validation process depends on the degree of uncertainty and controversy of the topic.

In the former case, if the issue is not a difficult or controversial one and concerns only one or a few experts, the process can be carried out by arranging a meeting, with one individual expert or a group of experts. Email correspondence can be used for instructing the experts. The most essential part of the process is discussion between the participants and, therefore, a forum that provides possibilities to discuss should be chosen, except in the simplest cases.

If the issue is difficult or controversial or requires expertise from several disciplines or if there is need for judgments of several experts representing the same field, an elicitation workshop is recommended.

3.3.3 Selection of experts

The Quality Manager selects the domain experts together with the safety analysts.

The selected issue or problem plays a major role in identifying the relevant types of experts. In the case of cross-disciplinary issues the combination of experts should reflect the nature and complexity of the issue. The amount of the experts from the same field is dependent on the nature of the issue and availability of the experts.

It is important that the participating experts are highly qualified but, due to the problems concerning the availability of relevant expertise, it may not be realistic to set any formal rules for their selection. It seems to be sufficient to contract the leading experts in the field when possible and document the merits of the selected ones, in the same way as at SKB.

SKB has created a database that contains information of the contracted domain experts (SKB 2006). A corresponding database could be useful for Posiva.

3.3.4 Selection of shared conceptual frameworks

Relevant *Structural and Contextual Descriptions*, specific to the elicitation situation are selected and possibly updated for each elicitation and validation process, according to the issue to be handled. The Quality Manager organizes the selection and the update and the safety analysts participate in the updating. If needed, the experts give domain-specific information for the selection and the updates.

3.3.5 Preparatory work of safety analysts

The safety analysts formulate their preliminary conception of input data uncertainties and document the conception and underlying assumptions and grounds in *Safety*

Analysts' Elicitation Form. The form guides the analysts in formulating, justifying and documenting the conception in an explicit way.

3.3.6 Training of experts

The interactive character of the procedure and the conceptual tools make it unnecessary to arrange any special training on elicitation for the experts. Special training is required only in the case of elicitation of probabilistic judgments. Descriptions of this kind of training can be found in reports on formal expert judgment elicitation for performance assessment concerning nuclear waste (e.g. Wilmot & Galson 2000) and for probabilistic safety analysis concerning nuclear power plants (e.g. Pulkkinen & Holmberg 1997, Simola et al. 2005).

3.3.7 Instruction of experts

The domain experts are informed by the safety analysts on the course of action in the elicitation and validation process. They are provided with the *Experts' Elicitation Form* and an explanation of the purpose and idea of the form is given to them. The experts are instructed on what is required from them and on the format in which the judgment(s) must be presented. The instructions focus on how to address uncertainty and on the importance of making the reasoning process as explicit as possible. The instructions are given via Email.

3.3.8 Independent work of experts

Within a defined period after the instruction the experts produce the initial judgments independently by using the *Experts' Elicitation Form* as a support. They present the requested judgments in the form and document their reasoning processes by answering to the questions.

3.3.9 Iterations

Depending on, e.g., the difficulty and controversy of the selected issue there may be need for iterations in producing the expert judgments. If this is the case, the Quality Manager organizes iterations and documents the procedure.

3.3.10 Validation of judgments for later use

Within a defined period after the production of the expert judgments a meeting with an individual expert or a group of experts is arranged by the safety analysts.

The analysts present and justify their preliminary conception of expert input uncertainties by using the *Safety Analysts' Elicitation Form* as a support. The expert(s) present(s) the judgment(s) and underlying assumptions and grounds with the help of *Experts' Elicitation Form* and comment(s) on the safety analysts' arguments.

The *Structural and Contextual Descriptions* are used to support the handling of the issue and the comparison of the safety analysts' and the expert' views with each other.

If the participants reach a consensus, a decision on the acceptance of the input for later use is documented. If the input is defined as tentative, reasons for the need for further work are documented. In addition, requirements for the way of carrying out the work and the identity of the person(s) responsible for the work are documented. It is important that there is a clearly defined procedure for the follow up for these cases and the unfinished steps of the process are documented appropriately. The safety analysts document the decisions in the protocol.

If a workshop is arranged, the Quality Manager invites the selected participants and organizes the workshop. This person leads discussions, takes notes during discussions, formulates conclusions of the discussions and documents the decisions. Finally, she or he summarizes discussions and documents the result of the workshop in the protocol.

3.3.11 Treatment of possible controversies

The way of treating possible controversies between the safety analysts and the experts is very important. Handling of different opinions is significant not only from the safety case point of view but also in the sense of interaction between human beings. Openness and fairness are needed to create mutual trust and understanding and to maintain motivation of all the participants.

The Quality Manager organizes a meeting for dealing with controversies. The other participants of the meeting are the responsible safety analyst(s) of the SAFCA Core Group, the relevant expert(s) and competent representative(s) of the Safety Committee (a member to whose expertise the matter belongs to). The discussions concentrate on

- identification of the core of the conflict,
- reasons for differing views,
- differences in prioritizations,
- conflicting goals,
- possible information gaps and misunderstandings,
- differences underlying disciplinary practices and ways of thinking and influence of the differences on handling of the issue,
- difficulties in availability of knowledge, and
- other possible reasons for disagreements.

If a consensus is not reached as the result of the discussions, the Safety Committee makes the final decision after the meeting.

The Quality Manager leads discussions, takes notes, formulates conclusions of discussions and documents the conclusions, the differing opinions and the way the disagreements have been handled.

3.3.12 Final documentation of the process

Part of the documentation takes place during the process. In the end of the process the Quality Manager documents the entire procedure in the protocol and includes the filled *Elicitation Forms* and the used *Structural and Contextual Descriptions* in the appendix.

Table 2. *Role of participants in the elicitation and validation process.*

Phase	Quality Manager	Safety analysts	Domain experts	Safety Committee
Selection of issue	takes initiative on elicitation as a consequence of QA review on reports	take initiative on elicitation on grounds of needs of safety analysis		
Selection of forum	participates in selection of suitable forum for the process	participate in selection of suitable forum for the process		
Selection of experts	participates in selection of experts	participate in selection of experts		
Selection of shared conceptual frameworks	organizes selection and possible updating of *Structural and Contextual Descriptions* relevant and specific to the situation	participate in selection and updating of the *Forms* and *Descriptions*	if needed, give domain-specific information for selection and updates if needed, comment on *Descriptions*	
Preparatory work of safety analysts	ensures that safety analysts are provided with *Safety Analysts' Elicitation Form*	formulate preliminary conception of input data uncertainties document the conception and underlying assumptions and grounds in *Safety Analysts' Elicitation Form*		
Training of experts	organizes training	in case of probabilistic uncertainties give training on expressing subjective probabilities		
Instruction of experts	ensures that experts get instructions and are provided with *Experts' Elicitation Form*	explain *Experts' Elicitation Form* to experts give instructions, via Email, for making judgment(s), focusing on how to address uncertainty		

Phase	Quality Manager	Safety analysts	Domain experts	Safety Committee
Independent work of experts	organizes experts' work		produce requested judgment(s) independently document judgments and way of producing them in *Experts' Elicitation Form*	
Iterations	if needed, organizes iterations and documents the procedure	guide iterations	make updated judgment(s)	
Validation of expert judgments for later use	In case of meeting: • organizes a meeting • invites experts • ensures that participants are provided with relevant *Structural and Contextual Descriptions* In case of workshop: • invites experts • takes notes in the workshop • documents in the protocol a summary of discussions and decisions on o acceptance of the input for later use o need for further work o need for a further meeting for handling of controversies	In case of meeting and/or workshop: • lead discussions • present and justify the preliminary conception of expert input uncertainties with the help of *Safety Analysts' Elicitation Form* • use *Structural and Contextual Descriptions* to support handling of the issue and comparison of safety analysts' and expert' views • participate in the discussions on the validity of expert inputs • formulate conlusions of discussions In case of meeting: • document in the protocol decisions on o acceptance of the input for later use o need for further work o need for a further meeting for handling of controversies	present expert judgment(s) and underlying assumptions and grounds with help of *Experts' Elicitation Form* comment on safety analysts' arguments use *Structural and Contextual Descriptions* to support handling of the issue and comparison of safety analysts' and experts' views participate in discussions and in making decisions on the validity of inputs	

Phase	Quality Manager	Safety analysts	Domain experts	Safety Committee
Treatment of possible controversies	in case of controversies organizes a further meeting • leads discussions • takes notes • formulates conclusions of discussions documents conclusions, participants' arguments and decisions in the protocol	the responsible safety analyst(s) of the SAFCA Core Group participates in discussions	the relevant expert(s) participate(s) in discussions	a competent member of the Safety Committee participates in discussions if a consensus cannot be reached, the Safety Committee makes the final decision on the validity of expert inputs after the meeting
Final documenta-tion of the process	documents the entire procedure in the protocol and includes filled *Elicitation Forms* and used *Structural and Contextual Descriptions* in the appendix uses the protocol in the development of *Descriptions* of the chain of activities producing the input, for QA			

The documentation of the entire process consists of descriptions of

- participants and their qualification,
- criteria for selection of experts,
- forum of the elicitation process,
- safety analysts' preliminary conception of expert input uncertainties and the underlying assumptions and grounds, presented in the *Safety Analysts' Elicitation Form*,
- expert judgments and the way they have been produced, presented in the *Experts' Elicitation Form*,
- possible iterations of production of judgments,
- structuring of the data input uncertainties, presented in the *Structural Descriptions*,
- descriptions of the safety context of the expert input, presented in the *Contextual Descriptions*,
- decisions on validation of the judgments for later use, presented in the protocol, and
- in the case of controversies, disagreements and the way of handling them, presented in the protocol.

The protocol is used in the development of quality assurance for the chain of activities producing the input. The documentation serves also as a tool for learning in the collaborative construction of the safety case.

4 PREPARATIONS FOR IMPLEMENTATION OF THE PROCEDURE

Before implementing the formal procedure, the generic formats of the *Elicitation Forms* and the *Structural and Contextual Descriptions* are designed, as described in chapter 3.1. Designing requires cooperation of the Quality Manager, safety analysts and substance experts. *Contextual Descriptions* are developed by utilizing existing descriptions when possible.

Development and updating of the tools require effort but, at the same time, improve interaction of the participating disciplines and, as a consequence, enhance mutual understanding and learning. Common consideration of the appropriate ways of presenting knowledge with the help of the *Forms and Descriptions* may bring about new challenges and ideas.

It is recommended to arrange a trial expert elicitation and validation process to find out the realistic possibilities to carry out the procedure and gain experience in its advantages and disadvantages in practise. It would be useful to organize a dry run for a case where interaction is needed between several disciplines. A special attention should be paid on the development of the conceptual tools for the trial.

5 SUGGESTED FURTHER DEVELOPMENTS

The management of quality concerning the safety case at Posiva should be developed as a whole. Expert elicitation and validation is part of knowledge production and should therefore be developed in connection with the development of the Models and Data reports and the overall quality assurance of knowledge production. In addition, the role of the Knowledge Quality Assessment (KQA) approach, concerning the biosphere (e.g. Hjerpe 2006), in the whole could be defined.

It would be useful to map the different tools for assessing expert judgments (e.g. peer review, elicitation, documentation) at Posiva and consider them in relation to each other. On the basis of the consideration the most appropriate tools for assessing judgments in each part of performance assessment could be defined (cf. Wilmot & Galson 2000). Different tools and approaches could be used to complete each other. For example, the possibility to utilize the means for assessing uncertainty, provided by the KQA approach, in the development of the *Structural Descriptions* could be considered.

Expert judgment is used in Posiva's daily work in the analysis and the assessments in informal ways through the expert's implicit and undocumented reasoning, inferences and scientific knowledge. In addition to the support given to the formal elicitation and validation of safety-critical issues, the suggested procedure provides elements for quality assurance of non-elicited judgment. Systematic practices could be developed to enhance transparency and traceability of expert judgments in the activity areas of Posiva. An important aspect in the development would be enhancing knowledge of connections and dependencies between different issues and areas to increase in formativeness and transparency of documentation. Another aspect would be the identification and definition of supplementary knowledge that can be used to enhance mutual understanding between the disciplines.

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