Producing nuclear safety expertise in the field of human factors

Grégory Rolina

24th EGOS Colloquium 2008: Upsetting organizations

Sub-theme 29:
Risky Organizations and the Organization of Risk Management

July 10-13, 2008

Producing nuclear safety expertise in the field of human factors

Grégory Rolina

Mines Paristech, CGS – Centre de gestion scientifique
60, boulevard Saint Michel
75272 Paris cedex 06, France

gregory.rolina@ensmp.fr
+33 1 40 51 90 96

Producing nuclear safety expertise in the field of human factors[1]

Grégory Rolina

Mines Paristech, CGS – Centre de gestion scientifique
gregory.rolina@ensmp.fr

ABSTRACT

Analysing interactions between regulators and regulated is a major research theme in risk management which is little explored, despite their assumed impact on the reliability of high-risk organisations. The question is particularly topical in the nuclear sector, which forms the basis of the research presented in this article. Several models of expertise and control activities taken from the scientific literature are presented before being compared with empirical data from research-intervention performed in conjunction with experts from the Institute for Radiological Protection and Nuclear Safety, specialists in human and organisational factors. The case studies show an expertise activity relatively remote from models presented previously, which take little account of the peculiarities of the system of relationships between the regulator and the regulated and do not place sufficient emphasis on the methods of constructing the bodies of knowledge of the expert assessment. Once the operations and products from the assessment process have been clarified, types of effectiveness are defined. These are used to suggest possible improvements and understand better the effects of an neglected activity. The results can seemingly be transposed to other institutional configurations and industrial sectors.

[1] This paper presents the results of research carried out jointly by the *Ecole Nationale Supérieure des Mines de Paris* and the Institute for Radiological Protection and Nuclear Safety (IRSN).

Researchers interested in high-risk organisations in recent years have often underlined the major impact of regulation modalities, of regulatory "styles" on the reliability and safety of facilities. The analysis of interactions between regulators and regulated is identified as a fertile research theme, especially by Mathilde Bourrier (2007) in a recent preliminary investigation: "hazardous plant regulation cannot be thought without the greatest attention being paid to the way in which regulated and regulators organise their interaction." (177); "it should be possible to include an understanding of the contribution made by control and expertise bodies to site safety in the programme of research into "creating" high risk and safety." (162) These aspects are also one possible extension to the work of Benoît Journé (1999; 2001) on managing the safety of nuclear power plants on a daily basis by the operating teams: "the analysis of the external control should be widened by direct observation of the operating mode of Safety Authorities." (1999)(418).

Despite the academic interest in this topic, there is still little empirical research likely to characterise the regulator-regulated interactions, with a few exceptions (Bonnaud 2002; Dupré and Etienne 2007; Wilpert 2008). "Actors in administration on the edge of sites - inspection or governing authorities - have rarely been investigated" (Bourrier 2007)(162) and are among the "blind points" identified by Mathilde Bourrier. The same has also been noted on the other side of the Atlantic by representatives of the trend for high-reliability organisations (HRO) in connection with the control of nuclear facilities: "nuclear utility/NRC relationships have received little attention at the microlevel. Most studies of the NRC have focused on macro issues such as the politics of regulation and regulatory reform rather on case studies of the working relationships between plants and NRC inspectors." (La_Porte and Thomas 1995)(114) The control authorities are just as concerned by this problem as the bodies responsible for supplying them with expertise. Pierre-Benoît Joly (2005) notes in a review paper that recent research on expertise "finally says little (…) about the way the experts regulate their relationships with their colleagues and other risk management players (…)" (160). This is particularly topical in the nuclear sector; the nuclear safety expertise bodies were in fact the subject of a symposium in 2007 with some sixty countries represented. The event aimed to share good practices in organising expertise processes and establish universal principles, despite the widely varying institutional contexts[2] likely to influence the

[2] Take for example the differences in articles of association of these expertise-producing bodies. It can be the department of an administrative authority, like in the United States or Sweden, or an independent authority combining expertise and research activities like in France, Germany and Belgium (see Le_Déaut, J.-Y. (1998). Rapport sur le système français

type of regulator-regulated interaction and the action logics of experts. In vain. The presentations only established similarities at a relatively abstract level; speakers advocated respecting the traditional values of independence and transparency whereas the audience - which included the author - deplored the lack of detailed examples which could perhaps have identified truly good practices.

The research presented in this article attempts to respond to these expectations, to unveil the wheels of a neglected activity, to highlight the logics of actors who noone could claim have any influence on the reliability of industrial facilities, but on which their recommendations continue to have an enigmatic effect. We shall therefore be led to qualify the regulator-regulated (expert-plant operator) interactions and identify their products and we shall ultimately attempt to provide answers to two questions: what are the elementary operations of the expertise production system? What is an effective expert assessment?

The little empirical research into the operation of bodies producing expert safety assessments must not prevent us from drawing on the theoretical progress in management and social sciences nor discussing the widely-accepted, implicit representations of expertise, control and regulation activities[3]. Different activity models will therefore be presented. Researchers interested in industrial risks often find it difficult to carry out field studies (Gilbert 2002b). We shall therefore expand on the methodological aspects of our work before briefly presenting a sample of cases analysed. Our results will characterise the nuclear safety expertise activity by comparing the case studies with the other models presented. The analysis will conclude with a section devoted to the effectiveness of the expertise studied.

---

de radioprotection, de contrôle et de sécurité nucléaire : la longue marche vers l'indépendance et la transparence.). Other variables also seem to influence the operation of these bodies, like the number of plant-operators; the presence of some fifty producers of electricity in the United States, in contrast to the monopoly in France, has a notable influence on the relationships between regulators and regulated (see Rees, J. V. (1994). Hostages of each other : the transformation of nuclear safety since Three Mile Island. Chicago, The University of Chicago Press.)

[3] The terms control and regulation have an equivalent meaning here. However, whereas researchers into management tend to use the term control, economists and political scientists talk more of regulation.

EXPERTISE AND CONTROL ACTIVITY MODELS

Several types of actors are involved in the organisation of nuclear safety in France: nuclear plant operators, the front line for the safety of their facilities; representatives of the Nuclear Safety Authority (ASN) which controls these facilities; experts from the Institute for Radiological Protection and Nuclear Safety (IRSN) commissioned by ASN to perform expert assessments. Nuclear safety expertise is therefore part of a control system. We shall thus present several forms of control and a regulation theory known as capture in addition to three expertise activity models.

The expertise canonical model

The judicial institutions rapidly brought in experts; thus "Roman law permits recourse to experts when know-how is required: the expert is approached to measure and assess." (Leclerc 2005)(27). This long history helps explain the maturation of organisation principles of the judicial expertise in our canonical model. We have taken them from the study by Olivier Leclerc (2005).

"The expert assessment stands out as a measure whereby specific knowledge is made available to a judge responsible for resolving a dispute. Thus, the expert assessment fulfils a decision aid function: the expert provides the judge with factual elements which he integrates in the decision process." (2005)(67). This division of roles is justified by the syllogistical structure of the judicial reasoning: "The major premise is the applicable rule of law, the minor covers the facts that must be held as constant and which form one or more conditions required to apply the rule of law. The conclusion of the syllogism is then drawn." (8). This theory ensures the independence of the judge and the expert.

The French judicial system has the particular feature of pre-selecting experts who will be named by the judge; the lists of approved experts held by the jurisdictions are "the central expert selection tool in French law." (200). "The competence of the expert is guaranteed by his being included in the list of experts and by his knowledge being certified before the hearing even gets under way. When he takes part in the hearing, the question of his competence is already dealt with." (253). This list system assumes 1) the transcendence of the knowledge with respect to the expert - as each expert can be replaced by another expert

registered on the same list; 2) the exteriority of the expert's learning process compared with the expert assessment process.

To complete our canonical model, let us evoke the sequence of an ideal expert assessment process: the expert, who has an exhaustive library of pre-established bodies of knowledge, is asked by the judge to reply to a question. He must therefore compile data, for which he enjoys tremendous freedom of action. He exploits these data by traditional, deductive reasoning and answers the judge. This marks the end of the expert assessment, which seems a relatively solitary process. When several experts are called as witnesses by the judge they are not expected to collaborate; each one submits his recommendations to the judge based on a succession of individual actions.

We can formulate nine proposals with these pronouncements which characterise the canonical model we are using as our basis (see frame 1).

E1. The judge instructs the expert to supplement the knowledge required for the verdict.

E2. The expert's intervention is restricted to the facts.

E3. The expert provides no legal appraisal.

E4. The expert's knowledge transcends the expert himself.

E5. The expert's learning processes are independent of the expert assessment process.

E6. The bodies of knowledge consist of a series of pre-established pronouncements and know-how combined with a set of specific data retrieved by the expert.

E7. The expert is free to decide on the operating modes he uses to answer the judge's question.

E8. The expert assessment process is individual.

E9. The expert's intervention is isolated and does not continue once the verdict has been given.

Frame 1: Nine proposals for the canonical expertise model

Criticism of the canonical model and the two alternative models

Certain proposals featured in the canonical model are fiercely criticised by Olivier Leclerc, especially E2 and E3. Based on reflections from the philosophy of law and knowledge, he asserts that the expert must of necessity consider the facts in a legal light; the

expert cannot be limited to the domain of factuality, itself also defined from categories of law. The syllogistical structure of the expert-judge relationship must therefore be revised and the normative function of the expert acknowledged.

The two alternative models below are taken from a review paper by Pierre Benoît Joly (2005). They are the result of research into politically-oriented scientific expertise by sociologists, political scientists and lawyers from the 1980s onwards, an era marked by a succession of health and industrial crises which severely undermined the trust placed by the man in the street in scientific expertise.

The first model emphasises the proceduralisation of expertise, intended to guarantee the principles of transparency and independence and the adversarial principle (Hermitte 1997; Roqueplo 1997; Decrop and Galland 1998; Godard 2003; Noiville 2003). The characteristic proposals of this model, qualified as procedural, are presented in frame 2.

E'1. Procedures guaranteeing the independence of the expert.

E'2. Procedures guaranteeing the transparency of the expert assessment process.

E'3. Procedures used to organise adversarial debates and ensure the expression of different theses.

Frame 2: Three proposals characterising the procedural expert assessment model

The second model raises more radical doubts over the traditional representations of the expert, which give him more a role of mediator between science and politics. It is based on the *hybrid forum* concept suggested by Michel Callon and Arie Rip (1992), intended to designate the heterogeneity of situations, constraints and demands faced by the scientists and the intangible nature of the science/policy division. This is "seeking a compromise or in what is more accurately termed a matching of positions" (146) which they believe characterises the activity of experts; "the expert assessment produces an assembly of heterogeneous elements considered sufficiently robust to have a certain stability" (147). Two characteristic proposals for this model are recorded in frame 3.

E''1. To formulate an opinion, the expert uses bodies of scientific knowledge, but he also considers economic, socio-political and regulatory constraints.

E''2. The process culminating in the formulation of the expert's opinion is made up of negotiations aiming at establishing a compromise, at "matching" the various stakeholders in sufficiently stable positions.

Frame 3: Two proposals characterising the hybrid forum model

Control forms

We have chosen here the work of William Ouchi (1979) from the many works about control; he has highlighted several control mechanisms in force in organisations. He distinguishes between three ideal-types of mechanism, the market (price control), bureaucracy (rule-based control) and a clan (tradition-based control). How then is a control form, hybrid if necessary, designed? "The essential element which underlies any bureaucratic or market form of control is the assumption that it is feasible to measure, with reasonable precision, the performance that it is desired. (…) The ability to measure either output or behaviour which is relevant to the desired performance is critical to the 'rational' application of market and bureaucratic forms of control." (843). The only possible form of control when results cannot be measured or rules of behaviour defined is clan control. Ouchi illustrates this situation using a research laboratory as an example: "the organization relies heavily on ritualized, ceremonial forms of control. These include the recruitment of only a selected few individuals, each of whom has been through a schooling and professionalization process which has taught him or her to internalize the desired values and to revere the appropriate ceremonies."(844). The resulting control forms are given in table 1.

		Knowledge of rules used to achieve the results	
		Perfect	Imperfect
Ability to measure the results	High	*Control by the result or by conforming to the rules*	*Control by the result*
	Low	*Control by conforming to the rules*	*Clan control (control of skill levels)*

Table 1: Control forms (adapted from Ouchi 1979)

What forms of risk and reliability control?

Applying Ouchi's reflections to nuclear risk control therefore requires prior answers to the following two questions: can the results associated with a safety production process be measured? Are the rules to achieve these results known?

The safety definitions proposed by Karl Weick then Erik Hollnagel suggest not: safety is a "dynamic non-event" (Weick and Sutcliffe 2001)(33); "safety is the sum of accidents that

do not occur" (Hollnagel 2006)(9). The words pronounced by an ASN engineer perhaps carry more weight:

> *"Ultimately, safety takes many forms and is difficult to measure. We surf over this difficulty: we tell EDF we want more, without really knowing what it is."* [Meeting on 13 February 2006]

We must therefore expect to see clan control forms if we follow Ouchi. The scientific literature and witness accounts from industrialists nevertheless seem to identify others.

Researchers who have studied the high reliability organisations, particularly in the nuclear (Bourrier 1999; Journé 1999), chemical (Colmellere 2008) and aeronautical (Amalberti 2001) fields have all noted the high (too many) number of procedures[4]. These sectors seem henceforth to be characterised by the dominance of a safety strategy based on anticipating at-risk situations (Wildavsky 1988; Journé 1999). In the nuclear industry, this is apparent through the extended use of notions of *defence-in-depth* and *barrier* and by the presence of a bureaucratic-type control (compliance with procedures, checking for barriers, requesting extra barriers).

In addition, nuclear power plant operators advertise widely the interest they have in operating experience, designated by the French three-letter code REX[5] and covering procedures for feeding back information in the event of an incident, triggering an analysis and processing statistics. These procedures are used in particular to account for the number of incidents and produce indicators for use as a form of control by results.

Our empirical data should therefore illustrate the composite nature of the nuclear risk control activity.

Capture theory

In the 1970s, American economists and political scientists (Stigler 1971; Peltzman 1980; Bardach and Kagan 1982) focused their studies on situations of public risk control. They introduced the notion of *capture* into the heart of their analyses, adopted under the public debates on deregulation in the United States.

[4] An EDF representative stated during a conference that a nuclear power plant was governed by 30,000 procedures!
[5] The three-letter code means « *Retour d'expérience* ».

The theory of capture is based on a simple observation: compliance with the requirements of the regulator costs the company money. The company therefore has every interest in persuading the regulator to tone down his system of rules. When this happens the regulator is captured; he champions the company's cause and the regulatory system is corrupted.

Ayres and Braithwaite (1992) have moderated this conclusion. They believe that the regulator can also win by collaborating and thus distinguishing between effective and ineffective captures. This is in fact a positive form of capture identified by La Porte and Thomas (1995) when studying the relations between the inspectors and the personnel of an American nuclear power plant.

The analysis grids we have used to interpret our field data are based on the various expertise models, the control forms and the notion of capture.

CONTEXT OF THE RESEARCH AND METHODOLOGY

We have compiled data on the activity of experts via a research-intervention[6] (Moisdon 1984; Hatchuel and Molet 1986; David 2000). Immersion is another possible term given the frequency and intensity of interactions between the researcher and the organisation's representatives. We have spent more than three years in the heart of a team made up of some ten experts. The purpose of the research-intervention, defined from the start of the collaboration, was to end up with a definition of the effectiveness of expert assessments produced by the team. The research should be the result of rigorous monitoring by the researcher of several files produced by the experts. In accordance with the research-intervention methodological requirements (Girin 1987), progress was presented regularly to the experts in a steering committee and to the management researchers.

We detail below the context elements used to situate the questions and research results.

[6] Also known as « collaborative research » (see Adler, N., A. B. R. Shani, et al. (2004). Collaborative research in organizations. Foundations for learning, change, and theoritical development, Sage Publications.; Shani, A. B. R., S. A. Mohrman, et al. (2007). Handbook of collaborative management research, Sage Publications.)

A team of human factor specialists

The experts at the Institute for Radiological Protection and Nuclear Safety who we came into contact with are human factor (HF) specialists, mainly trained in ergonomics, sometimes in sociology and management[7]. This speciality has emerged in the nuclear sector as a direct consequence of the Three Mile Island accident in 1979. Until then, safety experts focused on the design stage of nuclear facilities. Analyses of Three Mile Island showed the need to take account of working conditions for teams in the operations phase. Thus, in the early 1980s, the nuclear operators and safety institutions started welcoming HF specialists. Initially focusing on the design of man-machine interfaces, procedures and training programmes, HF expertise has gradually incorporated organisational safety factors (Rolina 2006), highlighted in particular by several surveys following resounding accidents (Reason 1987; Shrivastava 1987; Starbuck and Milliken 1988; Paté-Cornell 1990; Vaughan 1990; Perrow 1999).

Emmanuel Plot's recent work (2007) lists most of the HF issues. The author emphasises the problems of coordination, role definition and responsibilities, communication and decision-making modalities as had representatives of the high-reliability organisation group before him, who raised a series of criteria intended to characterise their high reliability (Rochlin 2001). However, researchers refuse to recommend an organisation model (Bourrier 1999); there is no denying that the corpus of bodies of positive knowledge as a basis for designing a safe organisation is far from complete. As Journé wrote about reliability criteria, "we have rather a succession of isolated elucidations." (1999)(71). These apparent gaps in knowledge prompt us to analyse how they are constituted in the context of expert assessments.

The institutional context of expertise

The activity of the IRSN HF specialists is part of an institutional architecture that has given rise to extensive criticism. In line of sight, the lack of any adversarial public debate, of

[7] This made the research far easier as ergonomists are particularly aware of the value of intervention (see for example Guérin, F., A. Laville, et al. (1997). Comprendre le travail pour le transformer. La pratique de l'ergonomie. Lyon, Editions de l'ANACT, Martin, C. and D. Baradat (2003). Des pratiques en réflexion. Dix ans de débat sur l'intervention ergonomique. Toulouse, Octarès Editions.)

any "nuclear law" (before 2006), the denunciation of a "phenomenon of expertise being monopolised by the promoters of technology" (Roqueplo 1995). This criticism, making the question of independence of experts and their eventual capture by industrialists essential, seems nevertheless attenuated by recent institutional transformations. In any case, this is the opinion of Claude Gilbert, a political scientist specialising in risk and crisis management: "This change comes from the clear dissociation gradually separating the organisations directly in charge of at-risk activities from the control authorities and expert assessment structures. (…). Thus, all the nuclear-related activities are viewed from two perspectives (…)" (2002a) (464). This movement towards expertise autonomy is accompanied by its proceduralisation and should therefore illustrate the relevance of the procedural model in analysing our material.

The various cases and type of data compiled

In conjunction with the HF specialists, we have selected a sample of three contrasting expert assessments. The first was devoted to reviewing the safety of an experimental reactor, the second to analysing several incidents occurring in an R&D laboratory and the third to the skills management of operating personnel in several nuclear power plants. Between March 2005 and September 2006, we attended some twenty meetings between the experts, plant operators and ASN representatives, carried out about fifty interviews with them and examined over a hundred documents.

We used this material to situate nuclear safety expertise in the HF field in relation to various expertise and control models.

NUCLEAR SAFETY EXPERTISE TESTED BY MODELS

We shall see that the data compiled only inadequately fit the models presented, which are deliberately vague about essential characteristics of nuclear safety expertise.

The expert's referral

The expertise start point nevertheless conforms in certain aspects to the canonical model. In the institutional context of nuclear safety, ASN acts as the judge and instructs the expert. The ASN representative needs the skills of the expert to pronounce on a specific question. This situation is illustrated in two of the case studies:

> *"We have the impression that experimenters take many liberties. Is it their fault for all that? I don't know. This is why I want an expert assessment".* ["Incident analysis" expert assessment. Interview with an ASN representative (29/11/05)]

> *"Do central departments have the means of ensuring that people are skilled? This is the central issue of expertise.* ["Skills management" expert assessment. Interview with an ASN representative (19/04/06)]

The reason for referral is different in the third case. A facility has been operating for ten years and ASN requests the plant operator to carry out a safety review. Once completed, it requests the IRSN experts to assess the work of the plant operator. This is automatically referred to a HF specialist to assess whether human factors have been taken into account in this safety review.

Generally speaking, following the referral by ASN and before the investigation commences, a major stage can be noted, during which the experts, in conjunction with the ASN representatives, specify the questions and methods for their investigation. This was especially the case for the skills management, where an analysis of the literature and several incidents identified the key phases in the skills management process to be analysed and the trades for which 360-degree interviews were decided.

The configuration here differs fairly comprehensively from that of the canonical model, where the judge expects an answer from the expert to a set question.

Once explained, the subjects of the analysis and expertise methods were presented to the plant operator.

Expert-plant operator negotiations

This first expert-plant operator interaction is nevertheless not restricted to a presentation. In two of the case studies, the plant operator vigorously discussed the relevance

of the expert's questions and methods. Thus, in the safety review, the plant operator did not agree to the HF specialist interviewing the operating personnel. The specialists were luckier for the skills management:

> *"We were afraid of their reaction to our insistence on the need for field work but they did not disagree."* ["Skills management" expert assessment. Interview with the HF specialist (29/06/05)]

However, the expert assessment subjects were negotiated furiously:

> *"We wanted to take the human resources policy into account more to assess the skills management. The plant operator did not agree, arguing that this area was off the subject."* ["Skills management" expert assessment. Interview with the HF specialist (29/06/05)]

Other negotiations met with more success;

> *"The plant operator reacted violently when we asked for documents on recruitment and redeployment [internal mobility]. They felt this was out of the frame. They justified their fear by invoking a sensitive social context. We fought over this point and finally they gave in."* ["Skills management" expert assessment. ». Interview with the HF specialist (29/06/05)]

These negotiations with the plant operator prior to the expert assessment itself invalidates proposal E7 in the canonical model, which stipulated that the expert was free to choose the operating procedures. Here the experts need to access the field. And to achieve this, the plant operator has to be convinced that the approach is relevant.

At the end of the expertise process, the results in the form of draft recommendations are also discussed with the plant operator. This was particularly true of the safety review:

> *- HF specialist: do you agree with our draft recommendations?*
>
> *- plant operator: we agree with the first recommendation, but it is difficult to produce an operating record for an organisation, so we'll give you some elements of operating feedback, OK? We agree with the second recommendation but with a delay of eighteen months. Do you agree?*
>
> *- HF specialist: OK. We agree.* ["Safety review" expert assessment. Experts-plant operators meeting (02/02/06)]

The negotiating nature of this expertise process partially validates proposal E''2, thereby bringing it closer to the hybrid forum model. However, in the cases presented here, it is not just the result of the expert assessment that is negotiated, as access to the bodies of knowledge is also at stake.

The expert's bodies of knowledge

The analysis of various cases invalidates the representation of bodies of knowledge that is a feature of the canonical expertise model. It is noted that the specialists have little recourse to a library of pre-established bodies of knowledge, a library also acknowledged as incomplete; the bodies of knowledge in fact are built up during the expertise process. Thus, several themes assessed under the safety review have emerged from meetings with the plant operator and in the incident analysis the specialist identified gaps in workstation ergonomics during a visit to the facility, for example :

> *"The labels are really not that easy to make out. You also have to be to the far left of the port whereas the pipes can only be connected using the right-hand remote handler."*[8] ["Incident analysis" expert assessment. Discussion with the HF specialist during the assessment (18/06/06)]

Having said that, not all the necessary bodies of knowledge come from the current expert assessment. To perform an assessment, it is also important to master prerequisites relating to the institutional operation. Thus, in the skills management case, service providers taking part in the expert assessment under the supervision of the HF specialist and who had never worked in the nuclear sector were in trouble.

> *"To write an assessment report means acquiring a vocabulary and ways of expressing yourself which demands a certain experience in the nuclear sector. And then there's a whole set of mechanics governing the relations between the expert and the plant operator which is not easy to grasp.* ["Skills management" expert assessment. Interview with the HF specialist (25/05/06)]

Contrary to proposal E5, it is clear that the expert's learning processes are far from independent from the expertise processes; without necessarily using pre-established bodies of

[8] After this observation, the specialist requested an ergonomic study on all the facility's workstations.

knowledge, the expert builds up his bodies of knowledge by interacting with the plant operator and learns how best to comply with the institutional requirements. The methodology used by the expert is not therefore identified by a simple compilation of data; it relies far more on an "epistemology of interaction".

This result, combined with the negotiating nature of the expert assessment, fully invalidates proposal E4, where the expert's body of knowledge transcends the expert himself. The collective aspects of the expert assessment can however reduce its "expert-dependence".

Collective and procedural expertise

The collective nature of nuclear safety expertise, which invalidates proposal E8, has several dimensions. The issues relating to expert-ASN and expert-plant operator relationships have already been discussed. In addition, our data has revealed the importance of horizontal and vertical relationships within IRSN.

The hierarchical relationships become particularly clear when the draft report is being validated. The many reviews within the Institute form a system intended to control the contingent aspects of the assessment process and reduce the "expert-dependence" of the expertise.

Coordination between the various specialists is also a decisive ingredient of the assessment production process. For example, in the safety review, no fewer than thirteen experts representing all special aspects of nuclear safety were mobilised. For the incident analysis, the HF specialist was able to collaborate with one colleague who knew the facility particularly well:

> *"He reviewed and corrected all the questionnaires I sent to the plant operator and explained the facility's operation and organisation to me. His questions helped me enormously when I visited the facility.* ["Incident analysis" expert assessment. Interview with the HF specialist (28/11/05)]

The collective aspects of the expertise are orchestrated by the Institute's procedures which include in particular the adversarial principle (E'3), as is illustrated by one of the maxims well-known to experts:

> *"At the end of the process, the expert and the plant operator must agree on the points of disagreement".*

In a word, the canonical model proves totally unsuitable for interpreting our data. In addition, whereas nuclear safety expertise illustrates certain of the proposed alternative models, fundamental aspects of cases analysed - the negotiating nature, the "interactive epistemology" as the basis for constituting bodies of knowledge - are ignored. Let us now turn to how the control and capture theories face up to reality.

The multiple control forms

A few of the expertise situations can be interpreted in the light of the Ouchi conceptual framework.

The three case studies have confirmed the presence of a control by procedures. Thus, in the context of skills management, the HF specialists were particularly interested in the existence of management systems.

> *"We are interested in the skills management system, its own systems, its procedures and their implementation; we wish to answer the question "does the plant operator have the means to assess and manage the skills?". We are not directly concerned with operator skills."* ["Skills management" expert assessment. HF specialist during a meeting (14/03/06)]

For the safety review, the HF specialist noted the lack of formalisation of the operating experience and questioned the plant operator on how the facility's operational documentation was validated and how many days were set aside to train operators in a certain type of risk. In general terms, it is accepted that these procedures, these human or organisational factors represent barriers. When the specialist finds a barrier missing, he can ask the plant operator to add it. Thus, in the safety review, the specialist asked the plant operator to formalise the operating experience and assess his reorganisation, on the assumption that this would have positive effects on the safety.

In this same case, this control form was not the only one noted. The specialist sought to assess the skill level of individuals involved in the plant operator's diagnosis. He was reassured by the plant operator:

> *"It's a company you have already worked with, HF specialists, who carried out this diagnosis."* ["Safety review" expert assessment. The plant operator during a meeting with the expert (09/06/05)]

The control by result was less apparent, even if the occurrence of several incidents in a facility justified launching an expert assessment and an analysis of a few incidents was used in the safety review.

The Ouchi control forms are nevertheless deliberately vague about a major expertise operation. In all three cases, the HF specialists focused on an investigation intended to *understand the chains of event likely to lead to an incident.* Thus, for the skills management, analysing the operator activity and a hundred or so interviews took place over several weeks. For the safety review, the specialist analysed a fuel loading operation during which he considered at-risk cases and listed the barriers. The incident analysis is the best illustration of an exercise of this type, for it aims in particular to reconstitute at a later date chains of events that have actually led to an incident.

Although this stage is tricky and costly - we have seen that field access had to be negotiated -, it improves the assessment of links between the HF and safety and therefore the effectiveness of barriers. This is an essential dimension; many authors have underlined the unproductive nature of barriers when there are too many of them (Journé 1999; Amalberti 2001; Hollnagel 2004). *It is therefore right that the expert assessment is not restricted to a control of procedures and barriers which ends up increasing their numbers, but that it incorporates this investigation stage with its wealth of learning that may well identify the most effective barriers.*

Is the expert captured?

It is difficult to answer this question unreservedly. We have emphasised the unavoidable negotiations with the operator which may put constraints on the expert assessment. Nevertheless, once the data had been compiled, the experts clearly developed and formulated their judgements independently - sometimes resulting in caustic exchanges with the plant operator - in all cases.

In addition, negotiations with the plant operator can have a positive effect on the expert assessment. We have seen that the plant operator can make the expert's work easier, above all when he wishes to use the assessment results. This was the case for the skills management:

> *"I wish our work to be useful to you, which is why I have selected the sites and discussed the trades to be used in compiling data.* ["Skills management" expert assessment. Interview with the plant operator (07/12/05)]

Some of the conclusions of the incident analysis were also welcomed by the plant operator:

> *"I think that an ergonomic analysis of workstations is a good idea, even if it will be difficult to implement. I am also for boosting the safety team numbers.* ["Incident analysis" expert assessment. Interview with the plant operator (07/07/06)]

The interest shown by the plant operator in the expert assessment can resemble a form of capture, with the expert in a way carrying out work on behalf of the plant operator. Although this may bother the supporter of independence[9], it is positive capture as it helps ensure better application of the assessment conclusions, thereby improving the operating dimension of its effectiveness. We wish to end this account by explaining the various types of expertise effectiveness.

CONCLUSION: HOW EFFECTIVE IS THE EXPERT SAFETY ASSESSMENT?

Although it is important to detail, as we have just done, the expertise production process to be able to discuss its effectiveness, it is equally important to list the various products. The first is the *expert assessment report* which involves extensive work in matching the players and which falls within the remit of the main requester, ASN. The process must respect the quality, deadline and cost constraints and produce persuasive arguments despite the lack of certainties available in the HF field. Adhering to the expert's recommendations ensures their correct application. This application, and more generally all the concrete *modifications* to the facility and procedures triggered by the expert assessment are the second product. Lastly, we have identified expertise as a learning process, unlike one of the proposals

[9] In other fields, several authors, including Olivier Godard, have highlighted idle fancies conveying this notion: "The independent expert, the soldier monk of the Republic, disunited from all things and all interests, but capable of accessing the body of knowledge without any kind of bias, does not exist. It is not the independence of experts you need to aim at but the independence of the expertise collectively handed down. This is even more true when the independence equates to the position of the dissenter." (2003)(10)

in the canonical model; the *bodies of knowledge* resulting from this process are the third expertise product.

A type of effectiveness can be associated with each of these products. The table 2 groups several effectiveness criteria identified by our investigations.

Product	Type of effectiveness	Effectiveness criteria
Expert assessment report	***Rhetorical effectiveness***	Matching experts, the hierarchy, plant operation adhesion, ASN satisfaction, etc.
Actions	***Operating effectiveness***	Modified procedure, more specific documentation, "concealed" effects ("safety culture building"), etc.
Bodies of knowledge	***Cognitive effectiveness***	At-risk activity analysis controlled better, new barriers identified. Publication of work, etc.

Table 2: The three types of HF expertise effectiveness

This analysis suggests improvement paths for the experts: increase the number of interactions between the specialists and their colleagues prior to the review to improve rhetorical effectiveness; encourage contacts with the ASN controllers to improve operating effectiveness; write a note on the lessons learned by the specialist following the expert assessment to improve cognitive effectiveness. It also seems that it can be transposed to other institutional configurations and other industrial risks (particularly aeronautical and chemical).[10]

[10] We wish to thank the experts at the Institute for Radiological Protection and Nuclear Safety most sincerely for their welcome and cooperation.

REFERENCES

Adler, N., A. B. R. Shani, et al. (2004). Collaborative research in organizations. Foundations for learning, change, and theoritical development, Sage Publications.

Amalberti, R. (2001). La conduite des systèmes à risques. Paris, Presses universitaires de France.

Ayres, I. and J. Braithwaite (1992). Responsive regulation. Transcending the deregulation debate. New York, Oxford University Press.

Bardach, E. and R. A. Kagan (1982). Going by the book. The problem of regulatory unreasonableness. Philadelphia, Temple University Press.

Bonnaud, L. (2002). Experts et contrôleurs d'Etat : les inspecteurs des installations classées de 1810 à nos jours. Sciences sociales. Cachan, Ecole normale supérieure de Cachan. **Thèse de doctorat:** 446.

Bourrier, M. (1999). Le nucléaire à l'épreuve de l'organisation. Paris, Presses universitaires de France.

Bourrier, M. (2007). Risques et organisations. Face au risque. C. Burton-Jeangros, C. Grosse and V. November. Genève, Georg**:** 159-182.

Callon, M. and A. Rip (1992). Humains, non-humains : morale d'une coexistence. La Terre outragée. Les experts sont formels ! J. Theys and B. Kalaora. Paris, Autrement**:** 140-156.

Colmellere, C. (2008). Quand les concepteurs anticipent l'organisation pour maîtriser les risques : deux projets de modifications d'installations sur deux sites classés SEVESO 2. Sociologie. Paris, Université de technologie de Compiègne. **Thèse de doctorat:** 409.

David, A. (2000). La recherche-intervention, cadre général pour la recherche en management ? Les nouvelles fondations des sciences de gestion. A. David, A. Hatchuel and R. Laufer. Paris, Vuibert**:** 193-213.

Decrop, G. and J.-P. Galland, Eds. (1998). Prévenir les risques : de quoi les experts sont-ils responsables ? Monde en cours. La Tour d'Aigues, Editions de l'Aube.

Dupré, M. and J. Etienne (2007). Eléments d'éclairage sur l'interaction régulateur régulé dans une industrie à risques. Risques industriels majeurs, sciences humaines et sociales. Toulouse.

Gilbert, C. (2002a). "Risques nucléaires, crise et expertise : quel rôle pour l'administrateur ?" Revue française d'administration publique **3**(103): 461-470.

Gilbert, C. (2002b). "From one crisis to the other : the shift of research interests in France." Journal of contingencies and crisis management **10**(4): 192-202.

Girin, J. (1987). L'objectivation des données subjectives. Eléments pour une théorie du dispositif dans la recherche interactive. Qualité et fiabilité des informations à usage scientifique en gestion. Paris, FNEGE.

Godard, O. (2003). Comment organiser l'expertise scientifique sous l'égide du principe de précaution ?, PREG CECO Laboratoire d'économétrie**:** 18.

Guérin, F., A. Laville, et al. (1997). Comprendre le travail pour le transformer. La pratique de l'ergonomie. Lyon, Editions de l'ANACT.

Hatchuel, A. and H. Molet (1986). "Rational modelling in understanding and aiding human decision-making : about two case-studies." European Journal of Operational Research **24**: 178-186.

Hermitte, M.-A. (1997). "L'expertise scientifique à finalité politique. Réflexions sur l'organisation et la responsabilité des experts." Justices(8): 79-103.
Hollnagel, E. (2004). Barriers and accident prevention. Aldershot, Ashgate.
Hollnagel, E. (2006). Resilience - the challenge of the unstable. Resilience engineering. E. Hollnagel, D. D. Woods and N. Leveson. Hampshire, Ashgate**:** 9-17.
Joly, P.-B. (2005). La sociologie de l'expertise scientifique : les recherches françaises au milieu du gué. Risques, crises et incertitudes : pour une analyse critique. O. Borraz, C. Gilbert and P.-B. Joly. Grenoble, Publications de la MSH-Alpes**:** 117-174 (257).
Journé, B. (1999). Les organisations complexes à risques : gérer la sûreté par les ressources. Etude de situations de conduite de centrales nucléaires. Sciences de l'homme et de la société. Spécialité Gestion. Paris, Ecole Polytechnique. **Thèse de doctorat:** 434.
Journé, B. (2001). "La prise de décision dans les organisations à haute fiabilité : entre risque d'accident et risque bureaucratique." Cahiers de l'Artémis. Organisation et stratégies industrielles **3**: 101-126.
La_Porte, T. R. and C. W. Thomas (1995). "Regulatory compliance and the ethos of quality enhancement : surprises in nuclear power plant operations." Journal of public administration research and theory **5**(1): 109-137.
Le_Déaut, J.-Y. (1998). Rapport sur le système français de radioprotection, de contrôle et de sécurité nucléaire : la longue marche vers l'indépendance et la transparence.
Leclerc, O. (2005). Le juge et l'expert. Contribution à l'étude des rapports entre le droit et la science. Paris, LGDG.
Martin, C. and D. Baradat (2003). Des pratiques en réflexion. Dix ans de débat sur l'intervention ergonomique. Toulouse, Octarès Editions.
Moisdon, J.-C. (1984). "Recherche en gestion et intervention." Revue française de gestion: 61-73.
Noiville, C. (2003). Du bon gouvernement des risques. Paris, Presses universitaires de France.
Ouchi, W. G. (1979). "A conceptual framework for the design of organizational control mechanisms." Management science **25**(9): 833-848.
Paté-Cornell, E. (1990). "Organizational aspects of engineering system safety : the case of offshore platforms." Science **250**: 1210-1217.
Peltzman, S. (1980). "The growth of government." Journal of law and economics **23**: 209-287.
Perrow, C. (1999). Normal accidents. Living with high-risk technologies. Princeton, Princeton University press.
Plot, E. (2007). Quelle organisation pour la maîtrise des risques industriels majeurs ? Mécanismes cognitifs et comportements humains. Paris, L'Harmattan.
Reason, J. (1987). "The Chernobyl errors." Bulletin of the British psychological society(40): 201-206.
Rees, J. V. (1994). Hostages of each other : the transformation of nuclear safety since Three Mile Island. Chicago, The University of Chicago Press.
Rochlin, G. I. (2001). Les organisations à "haute fiabilité" : bilan et perspectives de recherche. Organiser la fiabilité. M. Bourrier. Paris, L'Harmattan**:** 39-70.
Rolina, G. (2006). Savoirs et relations de l'expert. Le cas du spécialiste des facteurs humains de la sûreté nucléaire. XVe conférence internationale de management stratégique. Annecy, Genève.
Roqueplo, P. (1995). "Scientific expertise among political powers, administrations and public opinion." Science and Public Policy **22**(3): 175-182.
Roqueplo, P. (1997). Entre savoir et décision, l'expertise scientifique. Paris, INRA Editions.
Shani, A. B. R., S. A. Mohrman, et al. (2007). Handbook of collaborative management research, Sage Publications.

Shrivastava, P. (1987). Bhopal : anatomy of a crisis. Cambridge, Ballinger.
Starbuck, W. H. and F. J. Milliken (1988). "Challenger : fine-tuning the odds untill something breaks." Journal of management studies **25**(4): 319-340.
Stigler, G. J. (1971). "The theory of economic regulation." Bell journal of economics and management sciences **21**: 3-21.
Vaughan, D. (1990). "Autonomy, interdependence, and social control : NASA and the space shuttle Challenger." Administrative science quaterly **35**: 225-257.
Weick, K. E. and K. M. Sutcliffe (2001). Managing the unexpected. San Fransisco, Jossey-Bass.
Wildavsky, A. (1988). Searching for safety. New Brunswick, Transaction publishers.
Wilpert, B. (2008). "Regulatory styles and their consequences for safety." Safety science **46**(3): 371-375.