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Fukushima Daiichi Human and Organisational Factors

Part 3:
Implications for Regulatory Oversight of Human and Organisational Factors

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Summary

Since the accident at the Fukushima Daiichi Nuclear Power Plant on 11 March 2011, the Human and Organisational Factors (HOF) Section of ENSI has continued to consider what lessons can be drawn from it. On the tenth anniversary of the accident, it is publishing a report, derived from the findings, on the implications for its regulatory activity.

The accident from a systemic perspective

The analysis of the Fukushima Daiichi accident has shown that a variety of interacting human, technical and organisational factors contributed to both the origins and course of the accident. The occurrence of the accident cannot be explained by simple linear causal relationships. Likewise, it is not sufficient to focus exclusively on the HTO system (human-technology-organisation) of the Fukushima Daiichi nuclear power plant. Rather, the view must be extended to include the complex behaviour and network of the higher-level systems of various actors, including the supervisory authorities. Therefore, a systemic approach is needed both for accident analysis and in the operation and supervision of nuclear installations.

A crucial tool for applying and monitoring a systemic approach is an effective management system that takes into account the interaction between the human, technical and organisational components of the system. This management system is structured cyclically based on the principle of continuous improvement and covers elements of the relevant HTO system at the work, process and strategy level on the basis of the systemic approach.

Oversight topics taking into account the systemic approach

In its oversight, the HOF Section checks the degree to which the systemic approach has been taken into account by the supervised organisations alongside the elements of the continuous improvement cycle on the basis of concrete oversight items and priorities. These oversight items concern topics such as the purpose, vision and strategy of the system, the system boundaries and the external context of the system (at the strategy level), the processes and activities for effective and safe operation (primarily at the process level), the HTO-related influences for safety-related activities in the daily work of the members of the HTO system under consideration (at the working level) as well as the effectiveness of measures (at the process level) and the continuous improvement of system robustness and resilience (at the strategy level).

Oversight taking into account the systemic approach

A central principle of oversight is that the licence holders, and consequently the operators of nuclear installations are responsible for safety. The manner in which the supervisory authority interprets and performs its task in practice influences the capacity and will of the supervised parties to assume responsibility. For the oversight of complex HTO systems taking into account the systemic approach, not only are the oversight items important, but the way in which the oversight itself is performed is also significant.

In the literature, a distinction is often made between two basic «regulatory styles». A «compliance»-oriented oversight focuses on specified procedures and checks if these are strictly complied with by the supervised parties. In «performance»-oriented oversight, the supervisory authority assesses the performance of the supervised parties in respect of predefined criteria, leaving the way and method of achieving the objectives within the remit of the supervised parties. For complex HTO systems, oversight that is exclusively compliance-oriented, in particular for the supervision of human and organisational factors, is judged to be unsuitable and to hinder the assumption of responsibility by the supervised organisations. Complex HTO systems, such as the nuclear installations supervised by ENSI, therefore require a regulatory strategy and oversight approaches based on the systemic approach

that are suitable for coping with the complexity and context-dependency of these systems, and for strengthening, or at least not impairing, the systems' assumption of responsibility. It is not possible to meet these requirements with a «standardised», always invariable regulatory strategy and methodology. The concept of «responsive regulation» represents a possible way of dealing with the dynamics of complex HTO systems where oversight is concerned. «Responsive regulation» refers to a form of oversight which is not based on a uniform and invariable regulatory approach for all supervised organisations, but rather allows the supervisory authority to use different regulatory approaches and interventions, depending on the context and behaviour, the culture and the level of safety of the supervised organisations, enabling it to escalate from dialogue, conviction and self-regulation-based oversight through increasingly demanding and prescriptive interventions up to and including withdrawal of licences or prosecution.

The resilient organisation

In view of the high complexity of modern HTO systems, organisations must accept the insight and fact that, in spite of the best possible preparation for anticipated events, they cannot protect themselves against all possible (undesirable) eventualities with technical and organisational means or prepare themselves specifically for all possible eventualities. They must expect the unexpected and be able to deal with it when it occurs. In other words: They – and their employees – must be resilient. The performance of an organisation is resilient when the organisation can function as required under both expected and unexpected conditions. A central element of the resilience concept is the adaptivity (adaptive capacity) of the system under consideration (e.g. of an organisation) and the development and maintenance of this capability. It is not just a question of the ability to recover from hazards and strains, but of the ability to achieve the required performance under the variety of different conditions and to respond appropriately to both disturbances and opportunities. This concept of resilience is based on an understanding of safety, which in the safety sciences is called «Safety-II», as opposed to the traditional understanding of «Safety-I». In simple terms, Safety-I implies learning from things that go wrong, with the focus on «work-as-imagined», and is aimed at strengthening compliance. Safety-II, on the other hand, implies learning from things that go right with a focus on «work-as-done», and is aimed at strengthening resilience. The Safety-II view on safety focuses on an organisation's ability to guide the adaptability of personnel and systems by understanding how complex systems are for the most part successful and only occasionally fail. Safety-I and Safety-II are not mutually exclusive. Rather, the Safety-II perspective encompasses or extends the Safety-I perspective, thus making it possible to deal with situations in which the Safety-I approach is not (any longer) appropriate because of the increasing complexity of HTO systems.

Oversight against the background of resilience and Safety-II

The supervisory authority, through its oversight, influences the capacity of the supervised organisations to operate in a resilient manner. It must therefore design its oversight in such a way that it strengthens, or does not hinder, the development of practices and cultures in the supervised organisations aimed at reinforcing the resilience and integration of the Safety-II approach. Dialogue with the supervised parties is a central element of an appropriate regulatory strategy in the context of resilience and Safety-II. As part of its oversight, it is essential for the supervisory authority to understand how the supervised organisation functions on a day-to-day basis and which factors (including situational and context-related) influence this functioning. Oversight must be characterised by an insight into the normal functioning of the system.

The HOF Section has set itself the objective of questioning and further developing its oversight work in the context of Safety-II and resilience, and of developing

regulatory approaches and methods that appear suitable for strengthening the resilience and the Safety-II approach in the supervised organisations. For example, the focus of oversight activity in the human and organisational factors area should not be exclusively on compliance, but also on strengthening reflection and direct responsibility of the supervised parties in the sense of performance-oriented oversight as well as on understanding the normal, everyday functioning of the supervised organisation in its situational context. Therefore, the object of oversight should increasingly be «work-as-done», that is the way in which work is actually carried out, as opposed to «work-as-imagined», i.e. an idealised conception of how it should be carried out. This also means that attention in the oversight should not only focus on the «negative», but also on the «positive» or «normal». Such Safety-II-oriented oversight in the human and organisational factors area focuses on methods that promote dialogue with the supervised parties and their self-reflection.

Decision-making in emergency situations

Decisions play a central role in situations where resilience is required, for example in emergency situations such as those during the accident at the Fukushima Daiichi nuclear power plant. In such circumstances, decisions must be made under conditions of uncertainty, time pressure and stress and frequently without the necessary information being available. In complex emergency situations, decision-making is influenced by situational factors as well as factors that affect a single person or an entire group. Tools such as emergency procedures help to reduce the complexity of the situation by standardisation and reduction of the scope of action. On the other hand, however, the expansion of the scope of action through flexibility and learning also helps in dealing with complexity. In this respect, learning and integration of knowledge are focal points and learning opportunities play an important role in everyday operations.

In emergency situations, in addition to situation-related influences, there are also effects related to individuals that can influence the decision-making ability of individuals or groups of people, such as the so-called cognitive emergency response in individuals or groupthink where groups of people are concerned. Such person-related negative effects can be prevented, for example by training. Effective self-management is important in preventing a cognitive emergency response. People with good decision-making skills communicate effectively and assume leadership and responsibility. For example, to avoid groupthink, a rational and balanced information search is important, and each group member should be able to express their thoughts and arguments independently of the others. In complex situations, a planned approach based on clearly defined procedural requirements and the help of suitable decision-making aids (e.g. checklists) is recommended.

In summary, even in emergency situations, human abilities and characteristics as well as technical and organisational factors affect human decision-making performance in a wide variety of ways. Therefore, attention must be paid to all influencing factors.

Decisions are subject to the oversight of the HOF Section in a variety of circumstances. For example, they are considered in specialist discussions or inspections, in which formal process sequences are checked. Decision-making behaviour is observed during emergency exercises or licencing exams on the plant simulator or evaluated during event assessments.

Learning from other industries

Valuable insights and approaches in the human and organisational factors area can also be derived for nuclear safety oversight from the methods and experience of civil aviation.

A resilient organisation strives to be alert and flexible so that it can adapt at any time to the prevailing situation and is therefore prepared for unexpected situations.

A brief insight into the education and training for, as well as implementation into the daily work routine, of preparing and carrying out a flight by an airline cabin crew illustrates how preparation for the unexpected is performed on a practical basis in another industry. In addition to robust training in the area of safety, aircraft-specific training and an «on the job» introduction period, recurrent training and training sequences also help in exercises dealing with constantly varying situations and requirements. For example, the training teaches how to improvise if emergency equipment is missing and how to deal with new situations. Pre-flight crew briefings are also used to learn from each crew member's experience and to prepare for any unexpected events. Each member of the cabin crew pays attention to unexpected situations before the flight, during the safety check on the aircraft, passenger boarding, the preparation for take-off, during and after the flight, is aware of possible signals and prepares themselves mentally for various scenarios. The industry uses well-practised techniques and procedures.

Crew members, with their implicit and explicit knowledge, experience, training, alertness, situational awareness, flexibility and creativity, their decisions and the inherent scope of action they need to adapt their actions and behaviour are considered as safety factors prepared and qualified to respond to unexpected situations.

Outlook

This report is the starting point for further reflection and development of the oversight of the HOF Section against the background of the findings gleaned from the accident in the Fukushima Daiichi nuclear power plant and the current status of the safety sciences. From the identified topics and presented methods and approaches for future oversight, the HOF Section will develop an action plan for short, medium and long-term implementation.

1 Introduction

1.1 The tenth anniversary of the accident at the Fukushima Daiichi nuclear power plant

The 11 March 2021 marks the tenth anniversary of the accident at the Fukushima Daiichi nuclear power plant on and the associated memories of this event remain at the forefront of peoples' minds. ENSI employees can still remember the images and news that arrived in a steady stream and the growing certainty that highly significant events were playing out at Fukushima Daiichi.

Since the accident, the Human and Organisational Factors (HOF) Section has been considering the events during the accident as well as the causes of the accident. It discussed these in parts 1 (/11/) and 2 (/15/) of this series of reports. Since then, it has also been continuously working on the lessons it can derive for its own oversight. Although it is now ten years since the accident, recent findings have arisen from the experience of its own oversight activities and from the experience shared by other supervisory authorities across the world in international committees, from which the HOF Section has been able to draw conclusions for its own oversight.

The HOF Section of ENSI is therefore publishing a third report to mark the tenth anniversary. Unlike the first two reports, in which the main focus was on the analysis, i.e. the understanding of the accident and the circumstances (/11/, /15/), this report deals with the implications for the oversight activity of the HOF Section derived from the findings.

1.2 The HOF Section and its oversight activity

The HOF Section is the organisational unit within ENSI, which, based on the relevant legal and official regulations, monitors compliance with the safety-relevant aspects of the interaction of human, technical and organisational factors in a nuclear installation and reviews the associated projects. Its remit also includes periodically reviewing and, if necessary, revising the official regulations laid down in ENSI guidelines in the context of the human and organisational factors of a nuclear installation. It is based on internationally harmonised requirements as well as on the state of the art in safety research.

The HOF Section of ENSI is an interdisciplinary team consisting of work and organisational psychologists as well as engineers. Both professional groups undergo further training in the subject areas of the HOF Section both technically and in respect of oversight methods.

The oversight activity of the HOF Section includes in particular the following topics: effectiveness and continuous improvement of the management system; suitability, training and authorisation of licenced personnel; inspection of the reports of the supervised parties; design of organisational processes, work systems and work equipment, for example in the course of technical changes to a nuclear installation; measures to promote the safety culture, such as, among others, leadership, responsibility or decision-making; evaluation of events in the human and organisational context; configuration of the organisation and employee-related aspects in the context of organisational changes.

The legal mandate of ENSI is to ensure compliance with the applicable statutory and official regulations by the operators of nuclear installations (see Art. 72 NEA /36/). The implementation of this mandate is based on the view that oversight is not only about monitoring compliance with the regulatory framework but also about strengthening safety (/10/, /14/). It should also be borne in mind that in the human and organisational context, the above-mentioned regulations are often formulated in general and abstract terms[1] and cannot always be clearly measured. These issues are reflected in the diverse oversight methods used by the HOF Section. These methods are briefly described below.

The oversight methods used by the HOF Section can in principle be divided into methods of «target-actual comparison» (oversight «in the stricter sense», see /12/) or methods for triggering (self-) reflection on safety (oversight «in the broader sense», see /12/).

The «target-actual comparison» represents the classic «compliance» approach. ENSI checks whether the internal specifications of the supervised parties and the work carried out as part of the nuclear installation's everyday life comply with the statutory requirements. This category of oversight methods includes, in particular, inspections, the monitoring of reports of the supervised parties and the assessment of reportable events (see /13/). With «target-actual comparison» methods, topics for which clearly measurable requirements exist in the regulatory framework are monitored. The «trigger for (self-)reflection» occurs in group discussions with the help of a specific facilitation of the dialogue by ENSI. ENSI considers a capability for (self-) reflection as an indispensable prerequisite, for example, to learn from experience. This category of oversight methods includes, in particular, specialist discussions, in which subject areas with abstract and generally formulated legal regulations are examined.

1 | An example of such a generally formulated requirement can be found in Art. 5 of the Nuclear Energy Act NEA (/36/), where the establishment of a suitable organisation is required as a protective measure for nuclear safety. However, it is not specified what is meant by a «suitable» organisation.

Box 1 illustrates the oversight methods based on discussions with examples of oversight items of the HOF Section[2].

Box 1: Methods used by the HOF Section in discussions with supervised parties

- *Inspections:* Inspections are used in target-actual comparisons of oversight items. The HOF Section leads inspections of the management system, for example, and participates in the inspections of other sections. The latter are, for example, inspections that take place on site at the installation and whose inspection objects require greater organisation and coordination of the participating persons belonging to the supervised parties (e.g. performance of periodic tests, commissioning of modified plant parts).

- *Specialist discussion promoting a dialogue on safety culture* (see /12/): By means of these open and constructive specialist discussions, the aim of the HOF Section is to initiate self-reflection on the part of the supervised parties in respect of their safety culture. The discussions take place every three years and consist of two parts, each approximately three hours long and separated by a period of a few weeks. In the first part there is a discussion about a safety-culture related issue specified by the HOF Section. In the second part, the reflection is continued in greater depth. This deepening is based on findings and hypotheses that the HOF Section has developed from the first part of the discussion.

- *Exploratory specialist discussion:* This discussion also serves to trigger (self-) reflection. It is conducted by the HOF Section alone or together with technical experts from other sections. The announcement letter explicitly contains questions that are intended to trigger questioning and reflection on the issues to be discussed. These discussions usually last, depending on the topic, one and a half to three hours and are then closed. Exploratory specialist discussions are conducted to discuss more sensitive topics in the human and organisational context (e.g. on topics such as resources and leadership) or questions about organisational learning with the supervised parties.

- *Information discussion:* This type of specialist discussion is used to collect information, e.g. after events, in the case of organisational changes or in the context of technical modernisation projects. Specialist information gathering discussions are often conducted to understand changes that must be approved by ENSI or to obtain the necessary knowledge to be able to award a permit. The HOF Section also conducts an annual specialist discussion with the operators of the nuclear power plants on current topics and upcoming changes in the context of personnel or organisation.

This report deals with how the oversight activity and methods of the HOF Section are to be developed further on the basis of the findings from the accident at the Fukushima Daiichi nuclear power plant and based on recent developments in the safety sciences.

2 | The oversight activity of the HOF Section is not only based on discussions, but also to a significant extent on the documents and other data available in writing (e.g. safety indicators) of the supervised parties.

1.3 The topics in this report

The numerous event analyses of the accident at the Fukushima Daiichi nuclear power plant reveal a large number of contributing factors. A selection of these issues is covered in this report. In a series of workshops, the HOF Section identified the following main topics, which it considers to be central to its oversight activity and would like to deepen in the context of this report.

The **systemic approach** recognises the complexity of systems and considers them together with their interfaces and interactions in their entirety. The whole is more than the sum of the individual components. The need to apply a systemic approach to the operation of nuclear installations and their oversight is one of the key findings and recommendations from the analyses of the accident at the Fukushima Daiichi nuclear power plant (e.g. /31/). Section 2 of this report deals with the Fukushima accident from a systemic perspective and its implications for the oversight exercised by the HOF Section.

In view of the high complexity of modern HTO systems, organisations must accept the insight and fact that, in spite of the best possible preparation for anticipated events, they cannot protect themselves against all possible (undesirable) eventualities with technical and organisational means or prepare themselves specifically for all possible eventualities. They must expect the unexpected[i] and be able to deal with it when it occurs. In other words: they – and their employees – must be **resilient.** Section 3 of this report deals with the concept of (organisational with a digression to individual) resilience and the underlying understanding of safety (**«Safety-II»**). The section focuses on the importance of resilience and Safety-II to oversight. The HOF Section derives implications for its own oversight work from this.

The accident at the Fukushima Daiichi nuclear power plant has also shown the central importance of appropriate **decision-making.** This is the subject of section 4 of this report.

Section 5 contains a digression in which the topics under consideration are discussed in the context of **civil aviation.** It describes, using concrete and practical examples, how members of the flight crew prepare themselves for the flight and what methods they use so that they are always **prepared for the unexpected.**

Finally, section 6 summarises the **implications** that the HOF Section has identified for its oversight and its intentions regarding its implementation.

Within the individual chapters, in addition to the theoretical discussion of the topics and concepts, implications for the oversight of the HOF Section are derived. These are to be understood as long-term projects of the HOF Section and will be introduced gradually in future oversight work and continuously developed further. The report does not in any way claim to be complete. Rather, it serves as the basis and starting point for the continuous development of the topics and oversight methods and the following up of the relevant literature.

The report is aimed at a technically interested audience. Its aim is to deepen the treatment of the topics covered and to derive conclusions and methods directly applicable to oversight. In addition, it is intended to stimulate technical exchanges with interested parties (e.g. the supervised parties or specialists in the human and organisational factors area in other supervisory authorities or international working groups). This is why, where necessary, the report also uses specialist terms and concepts in the field of human and organisational factors.

2 The Fukushima Daiichi accident from a systemic perspective

The analysis of the Fukushima Daiichi accident has shown that a variety of human, technical and organisational factors contributed to both the origins and the course of the accident. Moreover, these factors were mutually interacting. The very dynamic course of the accident and the extremely complex situation during the accident have shown that the accident cannot be explained by simple linear causal relationships. It would also be an oversimplification to state that the accident was caused solely by insufficient technical precautions in the form of insufficient tsunami protection and a lack of technical emergency preparedness because the deficiencies in the design of the plant were, in turn, due to deeper underlying reasons in non-technical areas. Therefore, the question in connection with the cause of the accident is, why the deficits in the safety precautions could have arisen and why they were tolerated for so long. It turned out that the causes are not only to be found in the HTO system (human-technology-organisation) of the Fukushima Daiichi nuclear power plant, but extend far beyond that.

Box 2: HTO system (human-technology-organisation) and its behaviour

An HTO system, such as a nuclear installation, is a dynamic whole with a variety of different functions that are networked and interact with each other. A function refers to one or more activities to achieve a specific objective (output) as a sub-task for fulfilling the purpose of the system. Here, it does not matter who or what performs the function within the system: the organisation, the technology or humans. In an HTO system, functional activities are influenced by a variety of human, organisational, and technical factors (see Figure1).

The behaviour of HTO systems is complex because the functions interact with each other in a specific, dynamic relationship and in many ways (/44/). Interventions in such complex systems (e.g. work on site) not only affect individual functions, but can cause a variety of changes in neighbouring functions and affect the overall system (/44/). Due to the high degree of interconnectedness and dependencies and the possible combined effects, it is no longer possible to describe fully all functions with their properties and all potential interactions (/6/, /44/). Small, local deviations may spread through the system in a difficult to predict manner (non-linearity). Therefore, the predictability of system behaviour (output) and controllability are particularly demanding in complex systems (/44/).

When we talk about «system», «overall system», etc. in the following, this means an HTO system understood in this way.

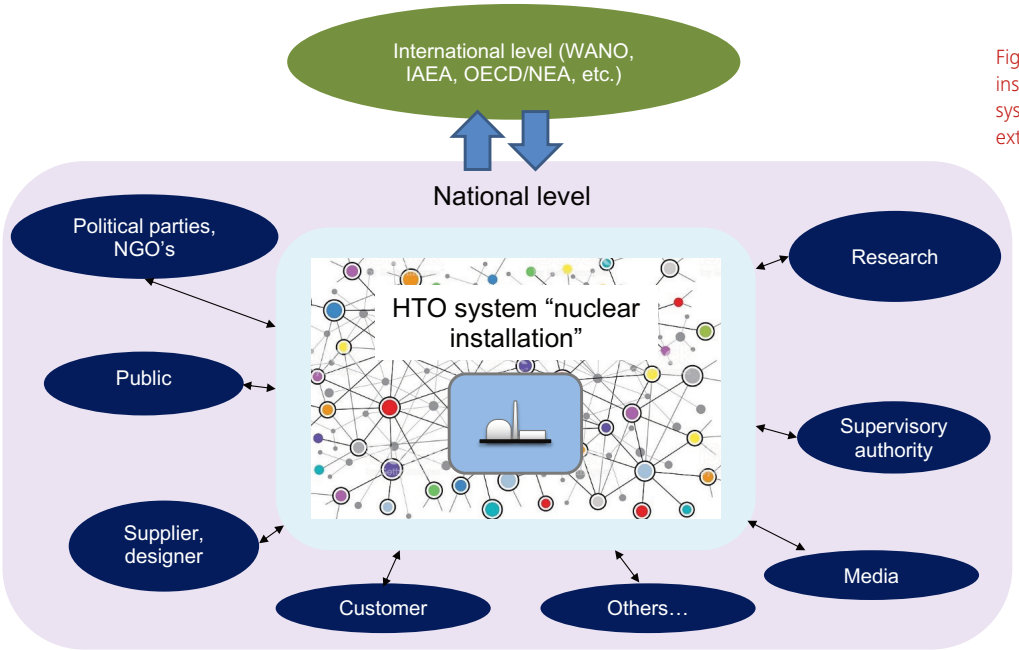


Figure1: The «nuclear installation» HTO system and its external stakeholders

External stakeholders, such as the parent company TEPCO as the licence holder, the supervisory authorities, the Japanese government, politics and the general public in Japan had a decisive impact on the safety of the Fukushima Daiichi nuclear power plant. In this sense, this was embedded in the overall nuclear power programme in Japan. For their part, these external stakeholders constantly interacted with each other. For the accident analysis, it was therefore necessary to go beyond the HTO system represented by the Fukushima Daiichi nuclear power plant and look beyond it for contributing factors to the cause of the accident.

Factors contributing to the shortcomings in the safety precautions of the Fukushima Daiichi nuclear power plant included factors affecting the parent TEPCO group as the licence holder. For example, an ineffective programme for the exploitation of national and international operational experience feedback led to an overly slow assessment and treatment of external threats such as earthquakes and tsunamis (/31/).

The accident analysis also showed that the supervisory authorities, in particular the Nuclear and Industrial Safety Agency (NISA), did not approach their oversight work in a sufficiently systemic way. Amongst other things, the 2015 IAEA report (/31/) stressed that the agency frequently considered issues based on compartmentalised thinking and did not address matters in a sufficiently comprehensive and systemic manner, i.e. not all aspects relevant to safety were included. Particular attention was paid to technical aspects, but little attention was paid to operational aspects or to human and organisational factors. In addition, the supervisory authorities were not inclined to learn from international experience and showed a tendency to isolate themselves. They frequently argued that foreign experience and approaches were not applicable in Japan (/31/)[ii].

Applying the systemic approach to the Fukushima accident gives rise to the following findings:

- On the one hand, the systemic examination of the accident analysis has enabled identification of a large number of contributing human, technical and organisational factors, and their mutual influence on each other. In doing so, it was necessary to go beyond the limits of the «Fukushima Daiichi nuclear power plant» HTO system and to include the external context of the various mutually-influencing stakeholders.

- On the other hand, the analysis also showed that the responsible managers were not sufficiently aware of the systemic approach to assessing and improving power plant safety precautions in the period prior to the accident. This is confirmed by the IAEA investigation report (/31/). This showed the importance of the continuous use of the systemic approach for effective safety precautions. Accordingly, one of the key IAEA recommendations from the analysis of the accident relates to the application of a systemic approach by all participating actors (/1/)[iii].

2.1 Consideration of the systemic approach

An essential requirement of the IAEA rules and regulations (/32/) is the need for an effective management system. This applies to all phases of the life cycle of a nuclear installation. In order to achieve and maintain an effective management system, the IAEA regulatory framework and the ENSI guideline on the organisation of nuclear installations, ENSI-G07 (/9/), emphasise the importance of taking into account the interaction between the human, technical and organisational system components. Managers at all levels of the organisation are required to identify and consider these interactions in terms of the effectiveness of the overall system in their implementation of the management system. The results of such regular checking of the effectiveness of the management system should be used to better understand the overall system and its multitude of interactions, and to continuously improve safety. The consideration of the systemic approach in order to achieve an effective management system has already been enshrined in national and international rules and regulations and its application in the context of continuous improvement cannot be avoided.

The requirements of the IAEA (/32/) for the systemic approach referred to are in no small part due to experience gleaned from the analysis of the Fukushima Daiichi accident. The question of how to apply the systemic approach is not easy to answer because the network of human, technical and organisational factors affecting a system such as a nuclear power plant leads to complex interactions of functions. Engineering backfits and an increase in the volume of organisational regulations have led to an increase in the number of functions and their level of interconnection in nuclear installations. Consequently, the system behaviour has tended to become more complex, making it even more difficult to understand and predict. This means that while adopting the systemic approach has become even more important, it also has become more difficult.

The topics shown in Figure 2 introduced in the report on «Human and Organisational Performance» of the Working Group on Human and Organisational Factors (WGHOF) of the OECD's Nuclear Energy Agency (NEA) provide assistance on which topics need to be addressed for the application of the systemic approach at the strategic, procedural and working level. Depending on which system is considered, the individual topics from Figure 2 need to be dealt with in more or less detail. For a technical safety system whose purpose is to feed coolant into the reactor in an emergency, the topics to be considered are primarily at the process and working level, whereas the entire nuclear power plant as an HTO system with its purpose of generating electricity also has to deal with important topics at the strategic level. The individual topics are explained in more detail in section 2.2.2 where their relevance for oversight is discussed.

These topics follow the principle of continuous improvement of the management system (PDCA principle «Plan-Do-Check-Act»), on the basis of which the effectiveness of the management system is also checked and continuously improved. The cyclical application of the topics is of prime importance because this is the only way to guarantee a continuous learning process that ensures progress in understanding and improving system behaviour. This is unavoidable given the complexity and dynamics of the system described above.

Any consideration of the topics runs from the macro level to the meso level to the micro level and back again in a cyclical sequence. The detailed view at the micro or work level is not limited to a particular level in the hierarchy. It concerns all hierarchy levels in an organisation, from the top management through to the implementing level.

The topics can be applied to any HTO system after the system limits have been defined. In principle, these system limits can be freely selected. The limits of a system relative to its environment, i.e. to a surrounding system, are not absolutely specified, but are to be defined depending on the respective perspective from which the system is looked at. For example, a particular department of a company is a subsystem from an organisational point of view, while from the point of view of the department, the organisation is to be viewed as part of the system environment (/44/). In nuclear installations, individual processes or technical systems can also be considered in this way. However, it should be noted that an exclusively isolated view of individual subsystems is not sufficient to understand overall system behaviour, since these subsystems are in turn interconnected and interact with each other. From a systems theory point of view, it therefore makes sense to include all functions that contribute to the result (output) of the system being considered, for example in terms of productivity, innovation or safety (/59/). Irrespective of the selected system limits, external influencing factors, i.e. influences stemming from the respective higher-level system, must always be included in the consideration.

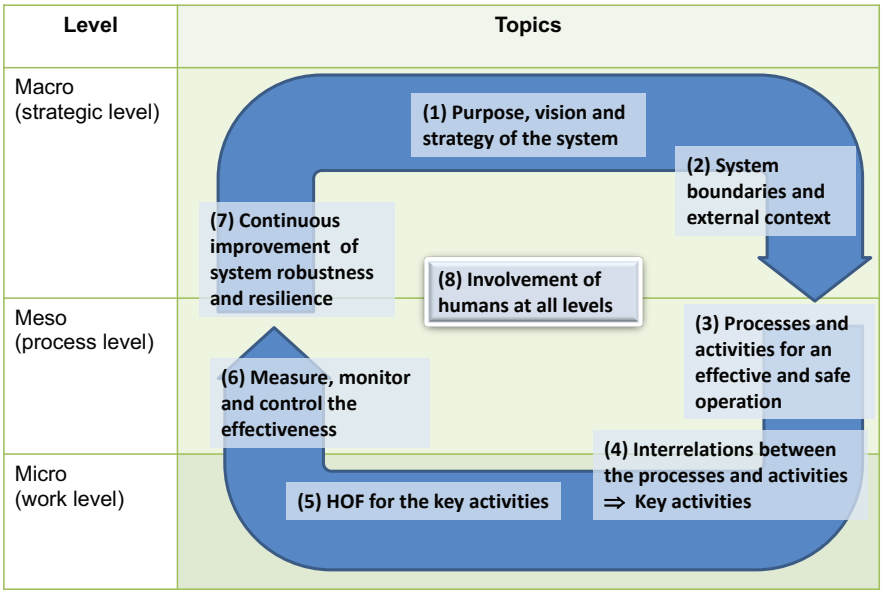


Figure 2: Continuous improvement cycle based on the systemic approach

2.2 Conclusion for oversight in respect of the consideration of the systemic approach

The accident at the Fukushima Daiichi nuclear power plant occurred because the safety and emergency preparedness for an external hazard in the form of tsunamis was insufficient. The operator TEPCO was responsible for plant safety. Nevertheless, the Japanese supervisory authorities had to verify that TEPCO effectively assumed this responsibility. To do so, they had to assess whether the safety precautions for the Fukushima Daiichi nuclear power plant were in line with the applicable regulatory framework.

As described above, the causes of the accident cannot solely be traced back to the lack of assumption of responsibility by the operator. The role of oversight in the higher-level nuclear power system in Japan, the relationship between operators and supervisory authorities and the underlying regulatory framework were also contributing factors.

Against the background of a collective assumption of sufficient robustness of the technical design of the plant in the face of external hazards (see /31/ and section 3), the supervisory authorities did not recognise that there were deficiencies in the safety precautions and therefore did not address them effectively.

This omission by the supervisory authorities was, of course, facilitated by an inadequate national regulatory framework. At that time, however, there were already international rules and regulations in place (/32/) that required the operator's management system to be effective. This implies that there was a process in place for continuous improvement which included an active search for opportunities and risks in the HTO system.

An important finding from the IAEA report (/31/) and the accident reports of the Japanese government is that the stakeholders involved, in particular operators and supervisory authorities, did not look actively enough for deficiencies in the safety precautions in the nuclear power system in Japan.

This lesson from the accident should also be a long-term guide for the operators and the supervisory authority in Switzerland. An active effort to discover possible latent deficiencies in safety precautions requires the basic attitude of improved understanding of the system under consideration, while at the same time accepting that this understanding will never be complete and finalised, but rather represents a continuous learning process due to the complexity and dynamics of the HTO systems under consideration.

In Switzerland, ENSI pursues this objective with its integrated oversight. A prerequisite for strengthening safety (mission taken from ENSI mission statement /10/) includes efforts to continuously improve the understanding of the monitored HTO systems under changing framework and boundary conditions. The question is how best to achieve this in the context of oversight activity and how to further develop oversight so that the supervisory authority contributes as effectively as possible to the continuous improvement of the safety performance of the supervised HTO systems.

In the context of the systemic approach, this is on the one hand about the type of oversight in the human and organisational factors area (section 2.2.1) and on the other hand about the focus on certain oversight topics (section 2.2.2).

2.2.1 Oversight of human and organisational factors in due consideration of the systemic approach

A fundamental principle of oversight is that the licence holders, and consequently the operators of nuclear installations are responsible for safety (see. Art. 22 NEA /36/ and /14/). The manner in which the supervisory authority interprets and performs its task in practice influences the capacity and will of the supervised parties to assume responsibility. In the worst case, it can even have a negative impact on them, for example by maintaining a too prescriptive regulatory style, i.e. by prescribing to the supervised parties in too much detail what they must do. In this context, a distinction is often made in the literature between two basic «regulatory styles», whereby these are usually not applied in one or the other pure form, but usually occur in a combination of both with different focus (/59/): «compliance»-oriented oversight (prescriptive oversight) as opposed to «performance»-oriented oversight (or goal-oriented oversight, results-oriented oversight). Compliance-or–iented oversight focuses on specified regulations and checks if the supervised parties strictly comply with them. In performance-oriented oversight, the supervisory authority assesses the performance of the supervised parties in respect of predefined criteria, leaving the way and method of achieving the objectives within the remit of the supervised parties (/59/). Wilpert (/59/) identifies a number of potential negative effects of (strict) «compliance»-oriented oversight, such as a sharp increase in (regulatory) requirements, excessive intervention by the supervisory authority in the day-to-day operations of the supervised parties, an increase in conflict and mistrust in the relationship between the supervisory authority and the supervised parties, an increasing demotivation and a tendency to blindly meet the regulatory requirements on the part of the supervised parties, a negative influence on learning for all involved parties and an increasing taking over of responsibility by the supervisory authority. He concludes that in complex HTO systems such a regulatory style is unsuitable, especially for the supervision of human and organisational factors. Within the framework of a performance-oriented oversight approach, self-assessment by the supervised organisation becomes more important. A crucial aspect of the regulatory work is the dialogue between the supervisory authority and the supervised parties in order to define appropriate performance indicators. Wilpert sees a culture of open and self-critical cooperation between the parties and a kind of common «management by objectives» as necessary, which results in a shared learning process for both sides.

Sidney Dekker (/6/) states that complex systems cannot be (exclusively) regulated by means of a compliance-based approach. Oversight is considered as part of the «protective structures» in the system, the purpose of which is to bring diversity into the system. Inspectors play a demanding role in this understanding of oversight and must be both «insiders» and «outsiders». This means that on the one hand, they must have sufficient knowledge and experience of the system being supervised so that they know what to look for and are able to detect weak signals. On the other hand, if they are too strongly «insiders», they will no longer be able to bring diversity into the system, i.e. an external view and thus impulses for further safety improvements, impulses which the supervised parties themselves are possibly no longer able to generate because of their direct involvement. According to Dekker, oversight implies being sensitive to the characteristics of complexity, for example interdependencies, interactions, diversity or learning. This means that inspections of system parts must in particular look for possible interactions with surrounding parts of the system or other systems. It is important to listen to different narratives, i.e. to include diverse perspectives from different actors from different parts of the system (/6/).

The explanations on oversight in connection with the systemic approach in complex systems show that it is not possible to define and apply a «standardised», always invariable regulatory strategy and methodology. The concept of «responsive regulation» represents a possible way of dealing with the dynamics of complex HTO systems in oversight. «Responsive regulation» refers to a kind of oversight which does not apply a uniform and unchanging regulatory approach for all supervised organisations, but rather uses different regulatory approaches and interventions by the supervisory authority, depending on the context and behaviour, culture and safety level of the supervised organisations (/2/[iv], /24/). To illustrate the approach of «responsive regulation», a so-called regulatory pyramid (see Figure 3) is generally used, which describes the escalation levels from oversight based on dialogue, conviction and self-regulation at the lowest levels, to increasingly demanding and prescriptive interventions up to the withdrawal of licences or prosecution. The role of the supervisory authority or the inspectors is accordingly, at the lowest level, the opening of a dialogue with the supervised organisation and its motivation to make certain changes. At the highest levels, it has at its disposal punitive instruments including strict sanctions (/52/).

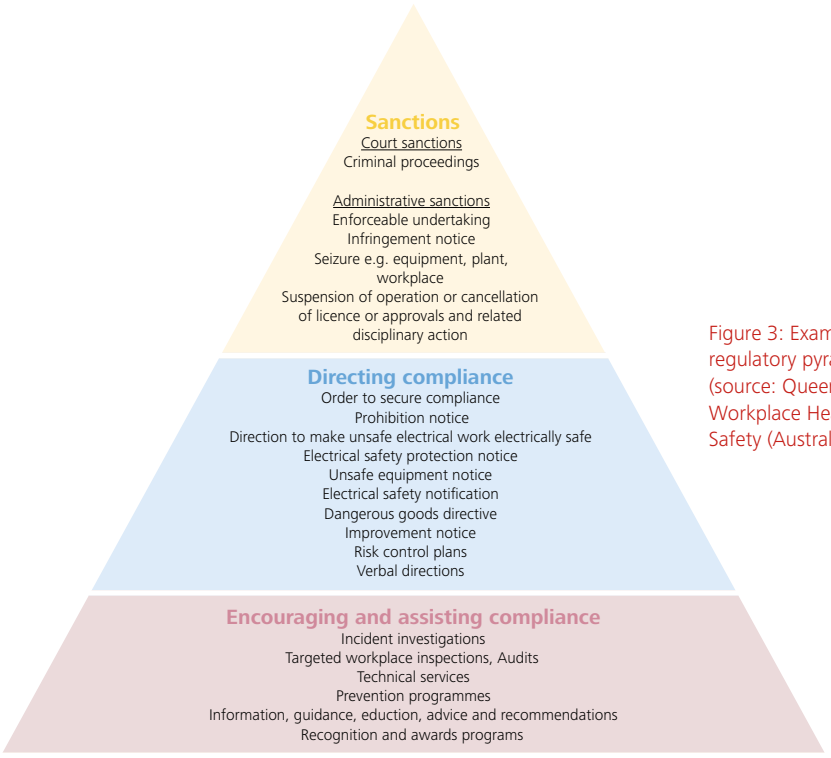


Figure 3: Example of a regulatory pyramid (source: Queensland Workplace Health and Safety (Australia) /63/)

2.2.2 Oversight topics in the human and organisational factors area as part of a consideration of the systemic approach

Based on the improvement cycle considering the systemic approach (see Figure 2) the HOF Section has derived oversight items from the topics mentioned there, at the macro, meso and micro levels, whose supervision provides a better picture of whether and how the supervised parties pursue a systemic approach for ensuring an effective management system (see Figure 4). As part of the supervisory procedure explained in section 2.2.1, the growing understanding of the topics and the HTO system should also increase the chances of improving the safety precautions.

The fundamental acceptance that, due to the complexity and dynamics of the HTO system, there may always be weaknesses in the safety precautions that are not known to the operators and the supervisory authority leads to the finding that, in parallel with the efforts to identify and address these weaknesses, it is essential to prepare for unexpected situations (see section 3).

At the macro level in Figure 4, **topic (1)** relates to the purpose and objectives of the system and the strategy to achieve them. In respect of the supervision of nuclear power plants in Switzerland, the special relationship between the licence holder and the plant manager can be identified as a key oversight item. Essentially, the responsibility for safety-related decisions cannot be transferred to third parties. The licence holder is responsible for the safety of its nuclear plant in accordance with Art. 22 of the Nuclear Energy Act (/36/). According to Art. 30 para. 4 NEO /37/, the licence holder must designate the plant manager who is responsible for the safe plant operation including the safety-related decisions. This results in a shared assumption of responsibility, which in the worst case can lead to a conflict of objectives between the licence holder, represented by the Executive Board appointed by the licence holder, and the plant manager.

Any unclear direction or strategy resulting from a possible conflict situation could have a negative impact on the people involved in the nuclear installation as an HTO system and thus unfavourably influence safety. The HOF Section has been looking at the topic of shared responsibility as part of its oversight for a long time and will continue to pursue it in the future.

Another important oversight item at the macro level is **topic (2)** «System boundaries and external context» in Figure 4. The boundaries of the HTO system under consideration must be clearly defined.

The external context outside the boundaries of the system of the nuclear installation may have an influence on the nuclear installation. This can take the form of political and economic influence, for instance. Another example is the negative public perception of nuclear energy, which may have an impact on the attractiveness of companies in the nuclear energy sector as potential employers (/50/). The consequences can be long-term problems in recruiting new employees, which could be exacerbated by a decline in training opportunities in the field of nuclear engineering. Economic pressure, which can arise from falling earnings on the markets, could be manifested in the form of cost reduction programmes for operators of nuclear installations. Concerning the oversight of human and organisational factors, the external context in which the nuclear installations operates must be closely monitored and social, political and economic changes need to be taken into account.

At the meso level, **topics (3)** «Establishing processes and activities for effective and safe operation» and **(4)** «Identifying interactions» are about designing the necessary processes and activities for the effective and safe operation of the HTO system. The processes and activities required for an HTO system such as a nuclear installation are so extensive that a complex network of interactions between them is created that cannot be fully understood, especially in terms of their overall effect. However, since an overall understanding of the system is the main objective and the basis for the

continuous improvement of the system, it is necessary to continuously learn from the ongoing operating experience. With appropriate awareness, this iterative learning process can result in a better understanding of the interactions between processes and activities. In addition, it will be possible to identify key activities with a particularly high degree of cross-linking and which are therefore particularly important for system performance.

The HOF Section has been supervising the regulation-compliant design of management system processes for many years and has identified special key processes of interest for safety. However, the interaction between processes and activities has still only been addressed in a rudimentary fashion. In this respect, this may be a future oversight focus in an effort to make progress in understanding important interrelations between processes and activities and gain an even more in-depth understanding of the system.

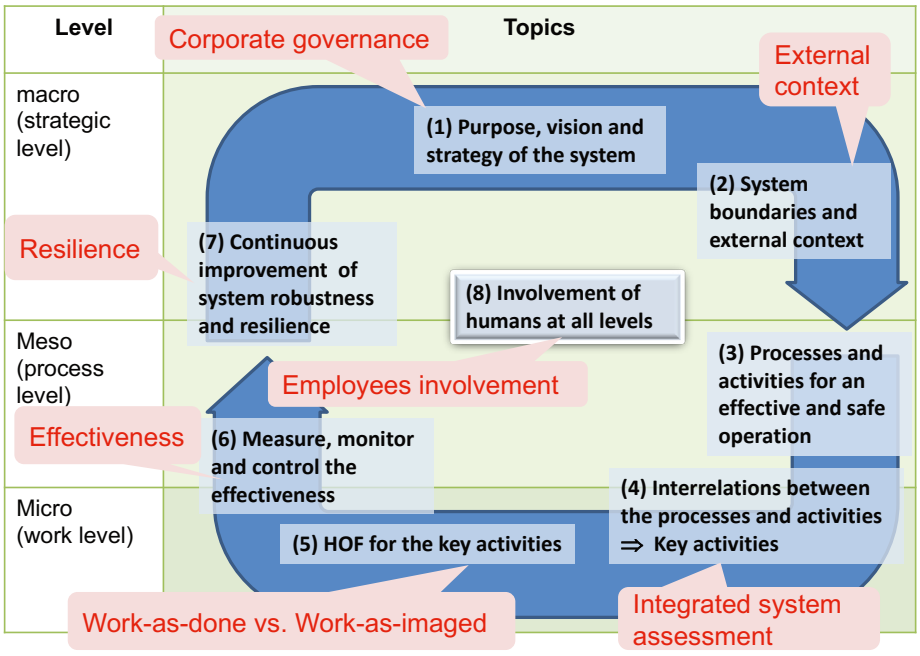


Figure 4: Derivation of oversight items from the continuous improvement cycle

The experience of the HOF Section so far shows that interdisciplinary cooperation is an essential success factor for the identification of interactions. For example, there have been events where a close collaboration between the specialists from different disciplines were required to analyse the causes both at the operator and at ENSI. A regular interdisciplinary exchange promotes this cooperation and provides an opportunity to identify and address cross-organisational interactions. In future, the HOF Section aims to promote this interdisciplinary cooperation within the operators' organisations through its oversight and to achieve an even more intense interdisciplinary exchange within its own organisation.

With the key activities identified under topic (4), i.e. activities with a particularly high degree of interlinking and therefore of particular importance for system performance, it is possible at the micro level to look more specifically at the influencing factors in relation to each of these key activities under **topic (5)** «Determining HTO influencing factors for key activities». From the supervisory authority's point of view, the focus here is always on the safety-related importance of these activities for the HTO system. At this level, it is now possible to carry out a human-centred assessment of the activity, including any influencing factors that make this activity a success. This approach is concerned with identifying human (individual abilities, situational awareness, mental state, etc.), technical (human-machine interface, accessibility, technical automation, etc.) and organisational (work documents, schedule, work equipment, etc.) influencing factors.

Especially when assessing reportable events caused by individual errors, the HOF Section does not primarily look for the causes of the event in terms of the person who committed the event-triggering error. Rather, it is a matter of identifying factors in the organisation that have contributed to an individual error at the end of a chain of actors that could have (safety-relevant) consequences.

The HOF Section will be informed of such errors if the corresponding events are reportable. The situation is quite different for the multitude of daily activities that are successfully processed in the HTO system of the supervised parties and where this success is moreover based on the fact that people, because of their abilities and motivation, are able to respond properly to the vagaries that are constantly occurring in reality and to make the necessary adjustments so that the activity can be carried out successfully. A detailed observation by the supervisory authority of daily activities successfully carried out can provide important information on the functioning of the HTO system in two ways. On the one hand, it is a question of recognising whether the requirements that have been defined at the strategic and process levels («work-as-imagined»[3]) are actually practicable and applicable at the working level. On the other hand, the adaptability of people and teams at the working level in the sense of a successful response to the unpredictable, everyday environmental fluctuations provides indications as to how well people and thus the system can respond to unpredictable events («work-as-done»[4]) (see also section 3). This is where it becomes clear how important an understanding of each individual actor in the HTO system is for the purpose, objectives and strategy of the overall system, so that performance at the working level can be adapted for the benefit of the system and its safety.

The reinforcement of oversight at the working level appears to be a useful step in further deepening the understanding of the two points mentioned above (see also section 3.4).

3 | The term «work-as-imagined» refers to the assumptions or expectations of how work should be carried out (see /29/). This is defined, for example, in the planning of work, in procedures or in processes of the management system.

4 | The term «work-as-done» refers to the way in which a work is actually carried out by the employees (see /29/).

Within the continuous improvement cycle, **topic (6)** «Effectiveness» is about evaluating the effectiveness of system performance in terms of the strategic and process objectives. The assessment should take place on as many layers as possible and should consider both quantitative and qualitative methods for assessing effectiveness.

The question of the effectiveness of measures is one that the HOF Section has been raising for many years in the context of learning from events in the supervised nuclear installations. The challenge is to bring together many findings from operating practice and to subject them as a whole to an assessment of effectiveness at the overall organisational level. In this way, the operating results can be used in an aggregated form in order to create the necessary decision-making basis for further strategic management by the senior management. Continuous, overall organisational learning is only possible if the potential for improvement is derived from the operating results and their assessed effectiveness at the strategic level, and leads to a readjustment of the objectives and strategy of the system. This readjustment should always bear in mind the purpose of the HTO system.

The HOF Section will continue to focus on the assessment of the effectiveness of the measures taken by the supervised parties as a basis for a well working continuous improvement cycle (/51/).

Topic (7) «Continuous improvement of system robustness and resilience» is aimed at the continuous improvement of the HTO system. On the basis of the findings from effectiveness checks, it makes sense to develop the system in two directions. On the one hand, this relates to identifying possible safety gaps as part of the precautions and then closing them with appropriate measures. Here, a continuous search for and assessment of risks as well as the resulting opportunities relating to the safety of the overall system is required. On the other hand, an effort should be made to improve the management of the unexpected. This results from the awareness that, in spite of extensive safety precautions, unexpected conditions or events can always occur. This is especially true for very infrequent crisis situations. A detailed consideration of the resilience of the HTO system and derived findings for oversight is discussed in section 3.

The drivers for the cyclic application of the systemic approach are the people involved in system performance. A sustainable learning process is only created if the participants at all levels are involved in the continuous improvement process (**topic (8)**). Each person needs to understand their contribution to the overall system and should be motivated to do this to the best of their capabilities and to constantly improve it.

Likewise, a differentiated discussion of the risks and opportunities regarding system performance should also take place, considering the interactions between the individual functions of the HTO system. Against this background, an ongoing interdisciplinary exchange and interdisciplinary cooperation should take place between the people in the system.

The question of the involvement of employees in the process of system understanding, interdisciplinary cooperation and their motivation to learn and improve has been addressed by the HOF Section for a long time within the oversight framework, especially in the context of safety culture.

3 The resilient organisation

The analysis of the Fukushima Daiichi accident has demonstrated that, over the decades, a deeply rooted collective assumption had emerged and was also continuously maintained among the Japanese nuclear industry, regulatory authorities, politics and society, according to which the Japanese nuclear power plants were sufficiently protected against external and internal events due to their robust technical design and the administrative and organisational measures taken, and that a large scale accident could not occur (/31/). This deeply rooted collective assumption led to the actors not anticipating such an event. As a result, the plants were inadequately designed and insufficiently organisationally prepared. The effects of the earthquake and subsequent tsunami waves impacted on them in an unexpected manner.

The prevailing basic assumption that the Japanese nuclear power plants were sufficiently safe also led to the regulatory framework containing inadequate specifications for addressing the tsunami risk. The supervisory authority, NISA, was of the opinion that, where emergency preparedness was concerned, it was not necessary to anticipate an event that would cause such large releases of radioactivity requiring protective measures since rigorous safety requirements as well as safety inspections and an adequate management of operations were already implemented in Japan[v]. Accordingly, the supervisory authority did not implement its regulatory activities in a sufficiently proactive and effective manner (see section 2) (/31/).

On the other hand, during the accident, in spite of extraordinarily difficult working and operating conditions, employees were able to improvise solutions, thanks to their tireless, selfless and courageous efforts, the knowledge and experience of those involved, and their ability to improvise using the few available resources and technical systems. The employees were able to adapt the organisation to the dynamic requirements of the situation and prevent the accident from becoming even more serious (/17/; see also the detailed description of the events in the first days after the earthquake and tsunami from the perspective of the people directly involved on site in part 2 of the ENSI report /15/).

3.1 Resilience

The events presented here relating to the accident at the Fukushima Daiichi nuclear power plant – the nature of the response of the site employees after the accident occurred, but also the lack of anticipation of the possibility of such an event and the correspondingly insufficient preparation as well as the lessons learned from it, both in Japan[v] and elsewhere – can be considered from the viewpoint of the concept of «resilience»[5,vi]. This concept is used in various scientific and technical disciplines (e.g. ecology, psychology, sociology, medicine, engineering, etc.) (see, for example /17/, /29/, /61/) and is also discussed in particular in the safety sciences in various sectors (e.g. in health care, air traffic control, etc. (/61/)). The concept of resilience has also been discussed in the nuclear industry, at least since the accident at Fukushima (e.g. /38/, /39/, /47/). One of the key conclusions drawn by the IAEA from its analysis of the accident at the Fukushima Daiichi nuclear power plant points to the need for resilience in organisations, whereby this ability must be developed well before unexpected events occur, i.e., under normal operating conditions. At the same time, appropriate means must be made available to respond to unexpected events (/31/[vii]).

There are many definitions for resilience in the literature. Depending on the field of application, different aspects and levels in the overall system are emphasised (see /17/, /43/, /65/). Common to the various concepts is the basic principle that all organised human and technical activities are to a certain extent characterised by inherent variability. Such variability is necessary for the successful functioning of socio-technical systems, as the conditions under which people operate constantly change and people therefore have to constantly adapt their activities to these changes and the current situation (/56/). As a further common feature, resilience implies the active use of different socio-technical resources (e.g. skills, knowledge, relationships between actors, technical equipment, values, creativity, etc.) to cope with those situations that threaten the objectives that are currently being pursued (/43/).

A central element of the resilience concept is thus the adaptivity (adaptive capacity) of the system under consideration (e.g. of an organisation) and the development and maintenance of this capability. According to Weick and Sutcliffe (/58/), resilience requires elasticity and recovery: in a «resilience episode», something is needed that can stretch and bend without breaking, and then at least partially return to its original form. However, this does not necessarily mean that the original state of the system must be completely restored. Adaptation also includes a transformation of the system so that it can cope with the new or changing requirements (see /65/). Resilient organisations are not error-free, but nevertheless they are not disabled by errors (see for example /58/[viii]). To put it another way: «resilient systems fail gracefully» (/65/, p. 18).

Socio-technical systems are often complex and operate in complex environments (see section 2; see also, for example, /28/). They are therefore confronted with uncertainties and must be able to cope with them on a day-to-day basis. A distinction is made between two basic ways of dealing with uncertainties in the organisational sciences: minimisation of uncertainties through standardisation and reduction of the actors' scope of action through centralised control on the one hand, as well as competent handling of uncertainties through flexibility, increasing the actors' scope of action and decentralisation on the other (/18/, /44/, /49/; see also section 4 of this report). According to Grote, an organisation or team must find a suitable balance between stability and flexibility, depending on the uncertainties and requirements with which they must cope or to which they must respond (/19/). An organisation must be able to adapt quickly to changing conditions and requirements (/21/). The ability to respond to changing requirements by adjusting the mode of operation is a feature of resilience in organisations.

Resilience is the subject of one of the five criteria of so-called «High Reliability Organisations» (HRO) («commitment to resilience» /58/). Based on the

5 | «Resilience» refers to the ability of people, alone or together, to cope with everyday, minor or significant situations by adapting their performance to the conditions. The performance of an organisation is resilient if the organisation can function as required under both expected and unexpected conditions (changes/disturbances/opportunities) (/29/).

understanding of Weick & Sutcliffe (/58/), resilience is a combination of keeping errors small, improvising emergency solutions to keep the system functioning, and absorbing changes in order to persist. Amongst other things, they consider the development of an extensive repertoire of skills as a central condition for the formation and maintenance of resilience, for example through the presence of personnel with diverse knowledge, experience and abilities, i.e. the presence of diversity within the organisation. As a result, there is a wide range of actions and the ability to improvise available for coping with unexpected situations.

Erik Hollnagel (/29/) differentiates between four potentials or abilities that must be available in an organisation for it to be able to function resiliently. Consequently, in Hollnagel's understanding, it is not the organisation itself that is resilient, but rather its performance or its functioning. The four potentials of resilience are:

- *The potential to RESPOND:* «Knowing what to do»; the ability to respond to regular or irregular changes, disturbances and opportunities by activating prepared actions, by adapting the current functioning or by inventing or creating new ways of doing things[ix];

- *The potential to MONITOR:* «Knowing what to look for»; the ability to monitor what may affect an organisation's performance – positively or negatively – in the near future (i.e. within the timespan of the current operation or work processes, e.g. the duration of a flight). The monitoring must include both the organisation's own performance and also its environment[x];

- *The potential to LEARN:* «Knowing what has happened»; the ability to learn from experience, especially to learn the right lessons from the right experiences. This includes both the small learning circle (single loop) from specific experiences and the large learning circle (double loop), which is used to change objectives[xi];

- *The potential to ANTICIPATE:* «Know what to expect»; the ability to anticipate future developments, such as potential disturbances, new requirements or constraints, new opportunities or changing conditions[xii].

The concept of resilience is often associated with the ability to respond to negative, undesirable events or conditions. However, as Macrae & Wiig (/43/) point out, an integrated concept of resilience should also integrate a positive perspective[xiii]. This accentuation of the positive or normal functioning and the development toward a more comprehensive understanding of the concept of resilience is also reflected in the evolution of the definition of this term over time (/29/). Therefore, resilience is not just a question of the ability to recover from hazards and strains, but rather of the ability to achieve the required performance under a variety of different conditions and to respond appropriately to both disturbances and opportunities[xiv].

Such an encompassing concept of resilience is based on an understanding of safety, which in the safety sciences is called «Safety-II», as opposed to the traditional understanding of «Safety-I»(/28/).

Box 3: Individual resilience

Individual resilience is not an oversight topic. Nevertheless, as a supplement to the resilience of organisations, the concept of individual resilience will be briefly outlined here.

An appropriate representation for individual resilience is the Lotos effect. The Latin term resilire means «bounce off» or «jump back» and can be observed with Lotos plants (/5/). Resilience is the ability to successfully handle challenges, difficult circumstances and crises. It is not an «all-or-nothing» property and, like personality traits, it is relatively stable. Nevertheless, resilience can be changed. There are various approaches for further developing and promoting personal resilience, for example through mindfulness training (/35/), embodiment exercises (/5/), autogenic training, meditation, yoga, etc.

The character strengths and virtues mentioned in positive psychology form a basis for the further development of personal resilience (/48/ and /23/). These are:

Virtues	**character strengths**
Wisdom and knowledge	Creativity, curiosity, ability to judge, love of learning, perspective
Courage	Bravery, perseverance, honesty, drive
Humanity	Love, kindness, social intelligence
Justice	Social responsibility, fairness, leadership
Moderation	Forgiveness, modesty, discretion, self-control
Transcendence	Appreciation of beauty, gratitude, hope, humour, spirituality

Organisations can benefit from resilient employees because performance, ideas and flexible thinking come from the employees. If employees are resilient, it strengthens the organisation (/1/). However, it would be fatal for both sides if a non-resilient organisation was kept going by resilient employees. In the extreme, this could mean that employees would constantly have to find ways and means to fulfil the company's performance without the organisation taking responsibility for functioning infrastructure and processes. It would just be a matter of time before employees burnt out, leaving the continued functioning of the organisation to other resilient employees.

The promotion of resilience within an organisation is an attitude of the organisation and an expression of the corporate culture that is reflected on many levels. Resilient teams are characterised by diversity, a wide range of knowledge and ideas as well as willingness to consider and draw from a variety of response options. In addition, a network based on trust is needed (/1/).

3.2 Safety-I and Safety-II

In simple terms, Safety-I implies learning from things that go wrong with the focus on «work-as-imagined»[3] (/28/), and is aimed at strengthening compliance. Safety-II, on the other hand, implies learning from things that go right with a focus on «work-as-done»[4] (/28/), and is aimed at strengthening resilience (/41/[xv]). The Safety-II view on safety focuses on an organisation's ability to manage the adaptability of personnel and systems («guided adaptability») by understanding how complex systems are for the most part successful and occasionally fail (/49/).

The following elements of Safety-II are described in the literature (see /28/[xvi], /29/, /41/):

- *Understanding of safety:* Safety is not defined as the absence of errors or undesirable events (Safety-I), but as the ability to ensure things go right.
- *Understanding of safety management:* Safety management is aimed at maintaining the adaptive capacity to respond effectively to unexpected events.
- *The role of people:* People are not seen primarily as risk factors, rather as a resource necessary for system flexibility and resilience.
- *Accident/event investigation:* The aim of event investigations is to understand how things normally go right, because this is the basis for understanding why they sometimes go wrong.
- *Risk assessment:* The assessment of risks is focussed on understanding conditions under which the variability in performance is difficult or impossible to monitor or manage.

Based on a resilience model developed specifically by the French energy company EDF for use in nuclear power plants, Park, Kim, Lee & Kim (/47/) developed a model of Safety-II and tested it using unexpected reactor trips at Korean nuclear power plants. The model, which is considered by the authors as a way of supplementing the traditional probabilistic and deterministic safety assessments, distinguishes five elements of Safety-II:

- *Anticipation:* Measures prepared before an event occurs and which are available. Elements of anticipation are emergency procedures, training programmes, personnel resources, organisational and safety culture as well as ergonomic human-technology interfaces such as alarm systems, displays, operating elements, support systems, etc. Accordingly, anticipation is a measure of the readiness of the emergency system with regard to an event.
- *Robustness:* The manner in which the emergency system determines the appropriate strategy depending on the event and in which it implements the required activities. Elements of robustness include system response, decision-making and execution.
- *Adaptation:* The way in which the emergency system develops the strategy to manage the event or adapt to it. Elements of adaptation are verification (the ability of the personnel to verify whether the current strategies, rules or procedures are appropriate for the current conditions) and reconfiguration (the ability of the personnel to adapt the strategy or rules based on the evolution of events).
- *Collective functioning:* The extent to which the plant personnel work as a team to accomplish a task or achieve a common objective. Elements of collective functioning are communication and teamwork.
- *Organisational learning:* The process by which the organisation generates new knowledge or modifies existing knowledge. The effectiveness of learning depends on which events and experiences are considered and how the events are analysed and assessed.

In his bachelor's thesis on the assessment of the level of integration of Safety-II in the oversight practice of ENSI's HOF Section (see section 3.3), G.R. Geeser (/16/, p. 14ff.) identified the following basic characteristics of Safety-II from the research literature on Safety-II:

- *Proactive:* Safety-II is a proactive approach. It requires the continuous anticipation of undesirable events. It requires an understanding of how the system under consideration works, how its environment and conditions develop or change and how functions depend on each other and influence each other.

- *Just culture:* A «just culture» is a prerequisite for the Safety-II approach. To understand the functioning of a system («work-as-done»), it must be possible to speak openly about «work-as-done» without fear of recrimination.

- *Consideration of the system as a whole:* Under the Safety-II perspective, a system is not divided into its individual components, but rather considered as a whole. The workflows and interactions in the system, its structures, barriers and resources should be understood as comprehensively as possible.

- *Breadth before depth:* In contrast to the Safety-I approach, where each event is considered unique and the event analysis looks for the specific causes of the event, each event is not seen as unique in the Safety-II approach, but as one that (in a similar form) has already happened in the past and could happen again in the future. Therefore, different paths that may have led to the event are examined, different perspectives on the event are considered, and patterns and relationships between different events are looked for.

- *Variability and execution adaptations:* Variability and performance adjustments are inherent properties of all systems and an integral part of day-to-day work (see section 3.1). They can result in success but also in failure. Therefore, the variabilities must be monitored and handled so that they can be detected in good time and contained if they would result in things going wrong, and supported if they would result in things going right.

- *Understanding of resources and limitations:* To identify and understand variability and execution adaptations, the available resources and constraints present in the working context must be understood.

- *Involvement of field experts:* To understand «work-as-done» in the system under consideration, field experts, that is the people carrying out the work, must be involved. In this way, it is possible to obtain a realistic picture of the on-site working conditions, and understanding of the overall system is reinforced.

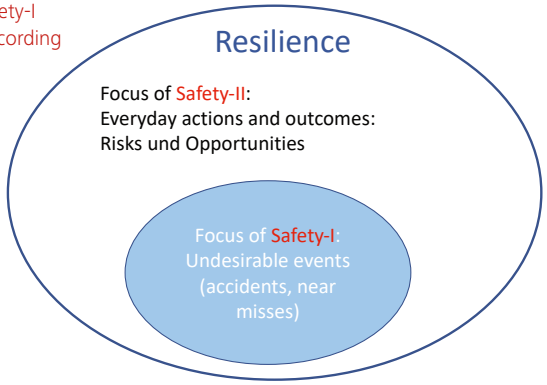
- *Focus on positive or normal functioning:* To understand success and failure, daily work and its actual execution must be understood. The differences between «work-as-done» and «work-as-imagined» must be understood. The focus is not on what problems exist, but on how they are solved.

Safety-I and Safety-II are not mutually exclusive. Rather, the Safety-II perspective encompasses or extends the Safety-I perspective (see Figure 5) and thus makes it possible to deal with situations in which the Safety-I approach is not (any longer) appropriate based on the increasing complexity of HTO systems (/28/). This understanding is based on the recognition that variability is inevitable or even necessary. The aim of safety management is to enable or achieve a safe variability («guided adaptability») and not to suppress variability (/49/). Provan et al. (/49/) make the distinction between Safety-I and Safety-II clear by means of the following comparison: Safety-I is «plan and conform», while Safety-II or guided adaptability is «plan and revise»[xvii]. Guided adaptability or Safety-II is therefore not about the choice between central control and adaptation, but about supporting safe adaptations. All actors (managers, those responsible for safety management, employees at the sharp end[6]) must (be able to) determine, depending on the context, when the safe working process will be achieved by following standardised procedures or when it will be achieved by adaptation (/49/[xviii]).

Such an integrated understanding of safety is set out by working group D of the Comité d'orientation sur les facteurs sociaux, organisationnels et humains (COFSOH) (/4/), which was created in 2012 by the French nuclear supervisory authority ASN (Autorité de sûreté nucléaire), under the denomination «sécurité construite», «constructed safety». It points out the necessary interplay between the two concepts of «sécurité réglée» («regulated safety», comparable to the concept of Safety-I) and «sécurité gérée» (or «sécurité adaptive», i.e. adaptive safety). Thus, the concept of «constructed safety» integrates the approaches described above for dealing with uncertainty (minimisation of uncertainties vs. competent handling of uncertainties) and the discussed balance between flexibility and stability as a central feature of resilience or the Safety-II approach in an organisation.

The concept of «constructed safety» (/4/) does not see safety as a fixed parameter. Safety is always context-sensitive and is always «constructed» anew in the day-to-day actions of the actors through decisions and reactions to the situations encountered. It is always the result of considerations and compromises between conflicting objectives and changing conditions. Trade-offs and compromises are made by all actors and at all levels of the organisation. This understanding corresponds to the assumption underlying the concepts of resilience and Safety-II of every system having an intrinsic variability of performance and behaviour and its continuous adaptation to different and changing requirements, which originate from the system itself or from the outside.

Figure 5: Relationship between the concepts of resilience, Safety-I and Safety-II (according to /28/)



6 | The expression «sharp end» refers to those activities which or those workers who interact directly with (dangerous) processes in their work role such as pilots, doctors, operators etc. They are therefore the people who work directly at the time and place where accidents (can) occur and where mistakes have direct consequences. In contrast to them are the activities and workers at the «blunt end», who influence safety indirectly, in that they have an influence on the conditions and resources of the employees «in the field», i.e. at the «sharp end». The conditions of the «sharp end» are thus determined by actions and decisions of other employees made at an earlier time and in another location (/26/).

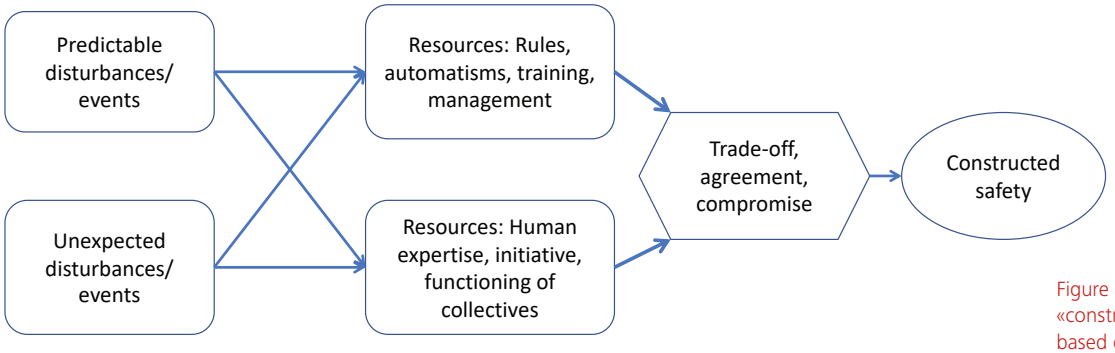


Figure 6: Concept of «constructed safety» based on /4/

In response to foreseeable or unforeseen disturbances and events, the concept of «constructed safety» does not assume an either/or application of either «regulated safety» (reaction to the disturbance by standardisation and formalisation) or «adaptive safety» (reaction to the disturbance by flexibility and learning). The reactions, actions and decisions of the actors are based on a combination of resources of both approaches, i.e. both on specified rules, trained skills and practised routines on the one hand, and on the expertise and initiative of the participants and their ability to innovate, adapt and react flexibly on the other (see Figure 6).

From the above, it can be deduced that a resilient performance is based on a predictable, but, especially in the event of an unpredicted, unexpected situation (e.g. a sudden event such as the accident at Fukushima or a more slowly developing crisis such as the COVID-19 pandemic) is always based on an optimal combination of the different approaches (standardisation/stability/Safety-I vs. flexibility/adaptability/Safety-II). This means, on the one hand, that prepared, immediately accessible and practised (emergency) measures, high competence and long-term experience of employees at all levels and in all functions in the handling of the technical systems and work equipment, in-depth knowledge of the plants and systems on the part of employees, standardised organisational processes and a high technical availability of the relevant systems, including important information about the status of systems and processes are necessary. However, on the other hand, the flexibility of structures and processes and the ability of the organisation to adapt its functioning as necessary depending on changing requirements, and the ability of personnel to innovate and improvise both at an individual but also at collective levels are essential (see also the remarks in section 4 of /15/).

Box 4: Leadership styles to promote resilience

The accident at the Fukushima Daiichi and Fukushima Daini nuclear power plants from the viewpoint of leadership in the field

The situation prevailing during the accident at the Fukushima Daiichi nuclear power plant represented an extremely demanding situation for all concerned, especially for the management (see part 2 of the ENSI report series /15/). Completely without external power supplies and, with the exception of units 5 and 6, without functioning emergency generators, virtually all monitoring instruments in the control rooms had failed. Most of the systems at Fukushima Daiichi had to be operated «blindly» from one moment to the next. The roads were flooded and destroyed, so that outside assistance and replacement materials could not be obtained in time to cool the nuclear

reactors and repair the damage (see /15/). Core meltdowns and/or explosions followed in four reactor units. The on-site employees were exposed to high doses of ionising radiation and were unable to find out about the circumstances of other family members due to the failure of communications.

The situation at the Fukushima Daini nuclear power plant, located about ten kilometres further south, also on the coast of Japan and also operated by TEPCO, was somewhat better (/22/). Electrical power was still available at Fukushima Daini: a power line and an emergency generator were functional. The monitoring instruments in the control room were working. Nevertheless, excellent leadership aptitude was necessary to prevent a worse outcome. Ultimately, Daini overcame the tsunami waves without either core meltdowns or explosions (/22/).

The approach of the site superintendent, Naohiro Masuda, at Fukushima Daini has been analysed in various studies (e.g. /22/) and was described as a positive example of resilient leadership. Particularly worthy of highlighting was Masuda's willingness to adapt his understanding of the situation and the way to proceed in the face of new setbacks and problems iteratively.

In emergency situations, it may not be possible to wait and decisions must be made quickly (e.g. in the case of resuscitation of an unconscious person; see also section 4). However, there are also emergency situations where it is possible to delay decisions. To delay in making decisions, even when everybody around is shouting for them, is very difficult to sustain and creates an unpleasant feeling (referred to in psychology as «cognitive dissonance»). People have a strong reflex to reduce uncertainties, unpleasant feelings and cognitive dissonances as quickly as possible in order to feel more comfortable again. This urge is so strong that in emergency situations people may become carried away in the heat of the moment and make decisions too quickly. However, if dissonances can be held at bay for as long as possible, the result is more time to think the problem through. Site superintendent Naohiro Masuda succeeded in doing this at Fukushima Daini.

Masuda had all employees gathered together on site and procured a whiteboard. He presented the available information on the whiteboard. Masuda did not make any overly hasty decisions, did not make any dramatic and out-of-touch speeches, and only distributed the information that was demonstrably proven to be reliable. He informed the employees about the strain of the existing uncertainty and doubts and gave them time to become aware of the extent of the situation (/22/).

In this way, Masuda allowed employees to participate in the process of «sense-making», in which existing information is interpreted in order to understand the meaning behind it (see /58/). Masuda and the employees worked together to develop an understanding of the actual situation (/22/).

Masuda and his employees came up against a lot of unexpected setbacks and problems. They were willing to question their knowledge of the actual situation time and again, to revise and iteratively adapt to the new obstacles, variances and disturbances. Problem by problem, they worked their way toward decoding, understanding and finally coping with the circumstances (/22/).

Resilient or situation-adaptive leadership

Grote (/21/) argues that organisational resilience is linked to the core competence of being able to function in different ways of working and to successfully switch back and forth between different modes of work and modes of operation (see also section 3.1). With resilient leadership, organisations, managers and teams can react in a situation-dependent manner to changing circumstances (variances and disturbances) (/40/, /57/).

Some situations may require stability (e.g. operation must continue to be stable and safe) and flexibility (e.g. a cause or solution must be found) at once. Managers are confronted with a so-called «managing paradox», for example, when routine tasks must take place simultaneously with exploratory, innovative tasks (/21/). Grote proposes that the management style be adapted to the stability and flexibility requirements of the situation. To do this, managers must be able to continuously review the stability and flexibility requirements posed by the current situation and make adjustments as necessary. Managers must be adaptive themselves and adapt their role and behaviour to the situation requirements (/21/).

Managers should have a wide portfolio of different management styles available for different situations. If the situation is associated with high stability requirements, directive specifications using rules are suitable. If the situation requires a high degree of flexibility, for example in informal learning and knowledge exchange, a shared team leadership in which a manager behaves like a work colleague of equal standing is appropriate (/21/) to achieve the best possible exchange in a dialogue. This low power distance behaviour can only be successful, if a manager is aware that there are situations in which hierarchical thinking can hinder safety (/21/).

As an example of situation-adaptive leadership, Yun, Faraj and Sims (/64/) show that in emergency medical situations, a direct management style was successful in complex situations with less experienced team members. By contrast, in less complex situations with more experienced teams, a supportive, personality-promoting, participatory management style (empowerment) was effective.

According to Grote (/21/), the requirements for managers to adapt their behaviour to the needs of the situation can be described as follows:

1. Managers must be able *to be adaptive themselves,* that is to say, to recognise the changes that are taking place and to adapt their own roles and behaviour to the changing demands of stability and flexibility.

2. *Organisational mechanisms* and instruments must be created *that support individual and collective adaptivity,* for example by ensuring that rules and standards not only promote stability, but also that rules are defined to enable flexibility, for example, procedures that specify goals or processes (as opposed to detailed instructions for action).

3. The third requirement relates *to the role of managers in the development of organisational culture.* In addition to the promotion of a mindful and informed culture, which is usually considered as a basis for resilience, the fundamental effect of culture as a powerful stabilising force, which supports the coordination of the actions of the members of the organisation and the integration of the work processes in decentralised and flexible modes of operation, should also be actively exploited. Grote envisages a *culture of interdisciplinary appreciation,* which brings together the entire knowledge of the organisation to find the best way to promote safety and to cope with conflicting demands, as beneficial for the resilience of an organisation.

3.3 The task of the supervisory authorities in the context of resilience and Safety-II

The strengthening of resilience and further development of a safety understanding in the sense of Safety-II in organisations that operate technologies and processes with a high hazard potential such as nuclear installations, can only be achieved with a systemic approach (see section 2). This means that the overall system in which these organisations are embedded must enable such further development. In particular, this means that the supervisory authority must support the supervised parties' development of their practices and cultures to reinforce the resilience and integration of the Safety-II approach. Depending on how the supervisory authority exercises its oversight and what kind of regulatory philosophy it pursues, it can strengthen or even hinder the development of the practices and cultures of the supervised parties (see /42/[xix]). Oversight instruments and practices aimed (exclusively) at controlling behaviour in a centralised and standardised manner seem to contradict the importance attributed to local innovation, flexibility, adaptability, problem solving, vigilance and improvisation relating to resilience (see /42/[xx]). Oversight, which places its primary or exclusive focus on compliance, can lead to the supervised organisations focusing primarily on compliance with regulatory requirements in order to avoid regulatory sanctions, at the expense of a loss of focus on the actual risks (see /42/[xxi]).

Nevertheless, little research has been done on the relationship between regulation and resilience and the role of regulation (oversight) in promoting or obstructing resilience and Safety-II (see /62/, /42/). Using the example of health care, Leistikov and Bal (/41/), note that in recent decades there has been a shift from compliance-based oversight to «responsive and reflexive» oversight[7]. The supervisory authorities are focussing less on regulations and documentation (i.e. on «work-as-imagined») and more on the context and interactions with the supervised parties. Leistikow and Bal see this development as a link to the Safety-II approach. Both in Safety-II and in a corresponding oversight approach, the aim is to understand situations in the context of their social dynamics, i.e. to recognise the meaning of an observed situation in its context[xxii]. This means that the focus is primarily on «work-as-done».

Leistikov et al. (/41/) derive the following consequences for oversight from considerations on Safety-II:

- *Understanding of safety:* As safety in the Safety-II approach is defined as the ability to ensure that things go right, dialogue is needed between the supervised parties and the supervisory authorities on what «right»[8] means and how the supervised parties can demonstrate their performance. This is likely to be a challenge in comparison with identifying errors and deviations, since the mere fact that a process is successful in its final result (objective achieved) and no (obvious) errors and problems have occurred does not necessarily mean that «things have gone right». Accordingly, the supervisory authority can ask the supervised parties for example to show what they define as «right» and whether a systemic approach is used, taking into account different perspectives. It can also examine to what extent the supervised organisations achieve a minimum degree of this «right» and how this is reflected in their «work-as-done».

- *Safety management:* As the focus of safety management is not on rigid rules, but rather on adaptive capabilities within the organisation, the supervised parties must demonstrate that they have the necessary structures and processes to effectively respond to unforeseen situations. The supervisory authority can therefore discuss with the supervised organisations how they have organised their safety

7 | See the explanations in section 2.2.1 for more information on «responsive regulation». «Reflexive regulation» draws on a regulatory understanding which does not build on a fixed approach, but is based on constant evaluation (reflection) of the current circumstances and problems, the suitability of the methods used and their (unintended) side effects as well as on the corresponding adaptation and further development of the methods used (/52/). The characteristics of reflexive regulation are its recognition of uncertainty, the participation of different actors (e.g. different authorities) and its focus on learning. Reflexive regulation is seen as a higher-level theory of various regulatory approaches, including «responsive regulation» (/52/).

8 | In connection with considerations on Safety-II and resilience, «right» means «normal». It is therefore not a matter of highlighting particularly good or outstanding activities, results or events, but rather of the normal, successful functioning in day-to-day operations, taking into account the daily variability of behaviour as well as of requirements and conditions. Therefore, in contrast to the Safety-I approach, the focus is not primarily on those situations in which undesirable results have occurred, errors have been made or disturbances have occurred, nor on those situations which are judged as particularly positive, but rather on those situations that are normal and in which the task is successfully performed.

management in respect of dealing with unexpected issues, and check, within the framework of inspections, the extent to which this is reflected in their «work-as-done». The authors argue that oversight should not be based on classical quantitative indicators or key figures, but rather on a qualitative, narrative discourse. For example, the supervised organisations may be asked to produce annual reports. There are no formal requirements for these reports. These then serve as a basis for discussion with the supervised organisations about their safety management and as a starting point for inspections of the actual work («work-as-done») in the everyday work of the supervised organisations.

- *The role of people:* If employees are expected to be a resource for flexibility and resilience, the work design must enable employees to assume this role. This requires, for example, a focus on (interdisciplinary) cooperation, easy accessibility to senior management for the safety concerns of employees, job satisfaction, etc. Employees must be sufficiently alert to recognise things that are going wrong, and be empowered to reporting them and acting accordingly. The task of the supervisory authority in this context is to ask the supervised organisations to show how they can ensure that employees can fulfil their role as a resource.

- *Accident/event investigations:* A combination of Safety-I and Safety-II seems appropriate to the authors. Both the investigation of the causes of an undesired event and the investigation of why the same process that went wrong in this case normally runs well, allow greater in-depth learning. In doing so, for example, classical investigation methods can be combined with a FRAM analysis[9] (see, for example /29/).

- *Risk assessment:* The monitoring and understanding of day-to-day performance variabilities should form part of the risk assessment by the supervised parties. The supervisory authority may therefore encourage or order the development and use of methods for recording and monitoring performance variabilities.

In summary, Leistikov et al. (/41/) advocate a shift in the supervisory authority's focus away from compliance towards consistency. Thereby, the question of how the «work-as-imagined» presented by the management is reflected in the organisation's actual daily performance («work-as-done») should be central. The oversight work of the supervisory authority should therefore not (primarily) be based on prescriptive oversight based on safety indicators, but rather on the supervision of the management system, with a particular focus on consistency between «work-as-imagined» and «work-as-done». The authors summarise this approach as a shift from regulatory «oversight» to regulatory «insight»[xxiii].

Working Group D of the Comité d'orientation sur les facteurs sociaux, organisationnels et humains (COFSOH) (/4/) presents similar considerations in respect of oversight, building on the concept of «constructed safety» (see section 3.2). It compares «normative oversight» with «constructive oversight», which is what should be strived for from the working group's point of view. «Normative oversight» assesses compliance, based on a retrospective view and on a defined standard. It is based on a Safety-I view and primarily searches for deviations from the standard. It is based on the hypothesis that the elimination of deviations or the ascertainment of conformity contributes to guaranteeing safety. In contrast, «constructive oversight» is not limited to the ascertainment of the

9 | Functional Resonance Analysis Method (FRAM): The objective of the FRAM method is to analyse how something is done, has been done, or could be done, and to present this graphically. Thereby, the functions that describe the analysed activity are identified and the interrelationships and interdependencies presented. Each function is described using the following six aspects and then associated with other functions: Input (I), Output (O), Preconditions (P), Resource (R), Control (C), Time (T). This results in a presentation of the functions of a system and their development in a specific situation or context, i.e. taking into account the performance variabilities. /27/ and /30/ in particular contain detailed information about FRAM.

conformity with the rules. The standards and rules are only one of the possible resources (see Figure 6). The aim of the inspectors is to assess the appropriateness of the actions carried out on the basis of the general objectives of the system under consideration. This type of oversight requires intensive interaction between the inspectors and the supervised persons, whereby the consideration of the context, the construction and the discussion of the criteria are of great significance. Together they work out a representation of the present (actual situation) and the paths to the future. In doing so, a learning process occurs on both sides.

A number of conditions must be met for «constructive oversight» to be successful (/4/). The inspector and the supervised person, must be aware that they share the same objective, namely improving safety. This requires mutual trust. The inspector must have good knowledge of the «field» and the actual framework conditions of the supervised activities (experience). The supervised person must themselves have a positive attitude and not want just to present a «good picture» of themselves. The oversight must therefore be benevolent (empathic, support-oriented), performed with integrity (honest, based on shared values) and (technically and socially) competent. It must be based on open dialogue, in which mistakes can be admitted and the fear of sanctions removed. The oversight is aimed at developing an understanding of the situation, not just finding mistakes. The inspectors focus on the day-to-day behaviour of the supervised parties to maintain safety and on the reality of the activities and situations («work-as-done»). This implies a methodological approach in the oversight, which allows access to the «reality» of day-to-day work. The COFSOH working group (/4/) recommends, for example, the use of mental simulation («what if…?»), discussions with different actors and direct observation. It also encourages the development of new oversight methods that promote immersion in situations and access to the actors.

Wiig, Aase and Bal (/60/) advocate the creation of «reflexive spaces[10,xxiv] « at the interface between the supervisory authority and the supervised organisations based on trust, dialogue, respect and a psychologically safe atmosphere. In this respect, oversight instruments, e.g. performance indicators or event assessments are not used (primarily) as a measure of the degree of compliance with regulatory requirements, but rather as a vehicle for creating reflexive spaces in which discussions about safety are conducted. The values of the indicators or the event reports are therefore not the focus of the supervisory authority per se, rather the reflection that is triggered by them. In such an oversight approach, the supervisory authority also uses «soft signals» from different sources. In doing so, it does not intervene directly in response to the signals, rather gathers them together, searches for their sense and meaning («sense-making») by placing them in the context of what is already known. With the findings (or hypotheses) gained in this way, it confronts the supervised organisation and enters into dialogue with it within the framework of a reflexive space. The aim of this procedure is to leave responsibility for safety with the supervised organisation as far as possible, while at the same time checking its ability and will to assume and bear this responsibility for safety, according to the motto «trust, but assess trustworthiness»[xxv].

Grote (/21/) stresses the need for the supervisory authority and the supervised organisation to have the same view as to whether and to what extent different modes of operation of an organisation are legitimate. Depending on the regulatory philosophy of the supervisory authority, it may be difficult to achieve this common understanding. For example, if the supervisory authority predominantly stands for a prescriptive regulatory approach and a world view based primarily on standardisation and centralisation (i.e. Safety-I), it is unlikely to accept an organisation of the supervised parties based on flexible, decentralised structures and

10 | Wiig et al. (/60/) consider «reflexive spaces» as physical or virtual platforms on which a reflexive dialogue between people takes place. The practice of reflexive dialogue is seen as central to learning processes, as it creates a bridge between implicit and explicit knowledge. Reflexive spaces can bring people together to reflect on current challenges, the need for adjustments or other demands in daily work, etc. They promote responsibility and feedback.

procedures. Therefore, according to Grote, open dialogue between the supervisory authority and the supervised organisations is essential in ensuring the operational flexibility required for a resilient mode of operation of an organisation[xxvi].

The HOF Section monitors the state of science and technology in the area of human and organisational factors and the safety sciences not only for the purpose of deriving requirements to be applied to the supervised organisations, but also strives to understand the implications of new concepts from the safety sciences for its own regulatory work and to constantly develop its oversight instruments and practices accordingly. For a number of years, the HOF Section has been addressing resilience and the Safety-II approach. Therefore, in 2016, it initiated a process of reflection on the implications of the Safety-II approach for oversight in the HOF area and, as part of a bachelor's thesis, carried out an analysis of its level of consideration to thoughts on Safety-II in its oversight practice of the time (/16/). The analysis showed that oversight must be more focused on «work-as-done» and the variability in the day-to-day functioning of the supervised organisation than was the case in earlier practice. Corresponding development potential therefore relates to a greater involvement of those employees who carry out the work at the «sharp end» and have the corresponding practical experience and expertise (so-called field experts). Since these persons are specialists in their field of activity, their involvement is indispensable in order to understand «work-as-done» (/16/).

The analysis resulted in a number of recommendations for action to the HOF Section in order to integrate the Safety-II approach more closely into its oversight activities:

- How field experts can be more involved in the regulatory activities of the section should concretised. This implies direct contact between the employees of the HOF Section and the employees at the «sharp end», i.e. at the workplaces on site, in the nuclear installations. For example, work observations could be carried out.
- Open dialogue on the Safety-II approach should be conducted with the supervised parties, e.g. within the framework of specialist discussions. This enables development of a common understanding of Safety-II and its practical implementation in oversight.
- The focus in oversight should not (only/primarily) be on the search for existing problems, but also on the question of how problems are successfully managed. To achieve this, Geeser (/16/) suggests that discussions with field experts be carried out. In each case, two field experts should participate in the conversation, as the dialogue between them could provide more comprehensive information and thus also strengthen understanding of the system. In addition, these discussions should take place at the workplace of those being surveyed so that the HOF Section representative can gain a feeling for the day-to-day work.

3.3.1 Interim conclusion

The considerations and approaches from the literature that deal with the question of an appropriate regulatory strategy in the context of resilience and Safety-II, lead to the conclusion that dialogue with the supervised parties must be a central element of oversight. In contrast to the Safety-I approach, in which deviations from a predefined target state are relatively easy to detect and assess, the Safety-II approach requires a consensus to be found on the target state in relation to the context, i.e. what can be assessed as «right», taking into account the respective context factors. There must be continuous discourse between the supervisory authority and the supervised parties, in which topics such as the day-to-day, «normal» functioning of the supervised organisation, the day-to-day variability of performance and behaviour, the different ways of functioning of the organisations in different situations and their handling of the unexpected or of uncertainty are explicitly reflected upon. For oversight, it is essential to understand how the supervised organisation functions on a day-to-day basis and which factors influence this functioning. *Oversight* must be characterised by Insight in the normal mode of operation, and there must be a common understanding of this mode of operation, the framework conditions, challenges and safety-related objectives between the supervisory authority and the supervised parties. Therefore, the supervisory authority must gain access to the «reality» of day-to-day work. An important focus of the supervisory authority will therefore be on «work-as-done» and on the consistency between «work-as-imagined» as defined by the supervised organisation and «work-as-done». Consequently, in its oversight activities, it must involve, not only the leaders, the employees who perform management tasks or specific safety-related functions, etc. (i.e. employees at the «blunt end»[6]), but also employees who perform the work «on-site», in the plant, in the workshop, etc. (i.e. «field experts» at the «sharp end»). In addition, it needs appropriate oversight instruments, with which, on the one hand it can monitor and assess the mode of operation of the supervised parties and, on the other hand, it can positively influence their resilience and Safety-II approach. Thereby, the supervisory authority itself needs to be flexible and adaptive, i.e. resilient, and to continually question its regulatory instruments and approaches – in the sense of reflexive regulation – and to adapt them to the changing requirements and to the situation of the individual supervised organisations. Oversight work against the background of Safety-II and resilience is therefore a demanding task in which the supervisory authority adopts a double questioning role, both in relation to the organisations it oversees and in relation to itself. This requires it to have a strong capacity for self-reflection in order to place its own role and influence on the safety of the supervised parties under constant self-scrutiny (/31/[xxvii]).

The HOF Section has set itself the objective of questioning and developing its oversight work against the background of Safety-II and resilience. The following section therefore draws practical conclusions for the future oversight of human and organisational aspects and proposes concrete ideas for commensurate oversight activities or the further development of existing oversight methods.

3.4 Conclusions for the HOF Section

Although not explicitly discussed in the literature cited here, in terms of the role of the supervisory authority in the reinforcement or influencing of the resilience or Safety-II approach of the supervised organisation, a distinction must be made between two – though not completely independent – aspects of regulatory oversight: *regulation*, i.e. the formulation of requirements in the form of guidelines, regulations, decrees, demands etc. on the one hand (see quadrant 1 in Figure 7) and on the other hand the *oversight activity* itself (see quadrant 2 in Figure 7). In terms of the oversight activity itself, it is then necessary to differentiate between the way of monitoring and the assessment of compliance with the requirements (oversight in the «stricter sense», see /12/; see also the orange arrows in Figure 7) and the striving to positively influence the safety and safety culture of the supervised parties through the exercise of oversight, for example by aiming to trigger self-reflection in the operator of a nuclear installation (oversight in the «broader sense»[11], see /12/) (see the upper blue arrow in Figure 7). Both aspects of the work of a supervisory authority have an effect on the ability and potential of the supervised organisation to function in a resilient manner. Conversely, culture, strategy and practice in the field of safety management on the part of the supervised parties have an effect on the manner of doing oversight of the supervisory authority (see the lower blue arrow in Figure 7). Considerations regarding a design of the oversight, which positively influences or at least does not hinder the resilience of the supervised parties, must therefore include both aspects (regulation and oversight activity). However, ENSI primarily deals with the implications of these resilience and Safety-II considerations for the regulatory framework (regulation) in the field of human and organisational factors as part of the drafting of new guidelines and the revision of existing ones[12] and are not the subject of this report (quadrant 1 in Figure 7). Accordingly, the focus of this report is on the *oversight activity* and on the approaches and methods used in oversight relating to resilience and Safety-II considerations.

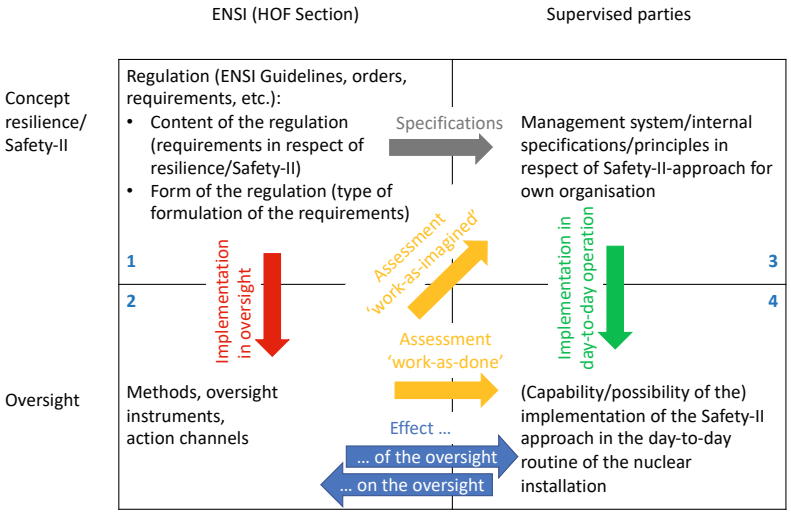


Figure 7: Oversight in respect of resilience and Safety-II from different perspectives

11 | As presented in /12/, in ENSI's understanding «oversight in the stricter sense» includes monitoring whether a licence holder performs its duties and then intervention when it does not. «Oversight in a broader sense» also includes triggering of the self-reflection of the licence holder by the supervisory authority. ENSI has formulated this comprehensive understanding of its own role in its mission statement (/10/). In addition to fulfilling its statutory mandate (in particular, Guiding Principle 1), it also considers the strengthening of the safety culture and the self-responsible action of the supervised parties as part of its task (Guiding Principle 2, point 3).

12 | This primarily concerns the guidelines ENSI-G07 «The Organisation of Nuclear installations» (/9/) and ENSI-B10 «Basic Training, Recurrent Training and Continuing Education of Personnel in Nuclear Installations» (/8/).

The considerations of the HOF Section on the (strengthened) integration of the Safety-II approach into its future oversight are presented below. In doing so, it is not the aim to make a radical change to oversight by abandoning the Safety-I approach and replacing it with the Safety-II approach. Rather, it is a question of considering both approaches in their complementarity and taking them into account in oversight in the human and organisational factors area. The ideas and methods discussed below are therefore intended as a supplement to the oversight methods (not discussed here) that are more likely to be assigned to the Safety-I approach.

Moreover, it should be noted that even in the past quite a few Safety-II elements were already put into practice in the area of human and organisational oversight. Therefore, these are not completely new ideas and approaches that will, going forward, be applied in oversight from some particular point in time. Rather, it is much more about a smooth transition toward an integrated oversight approach which takes equal account of Safety-I and Safety-II.

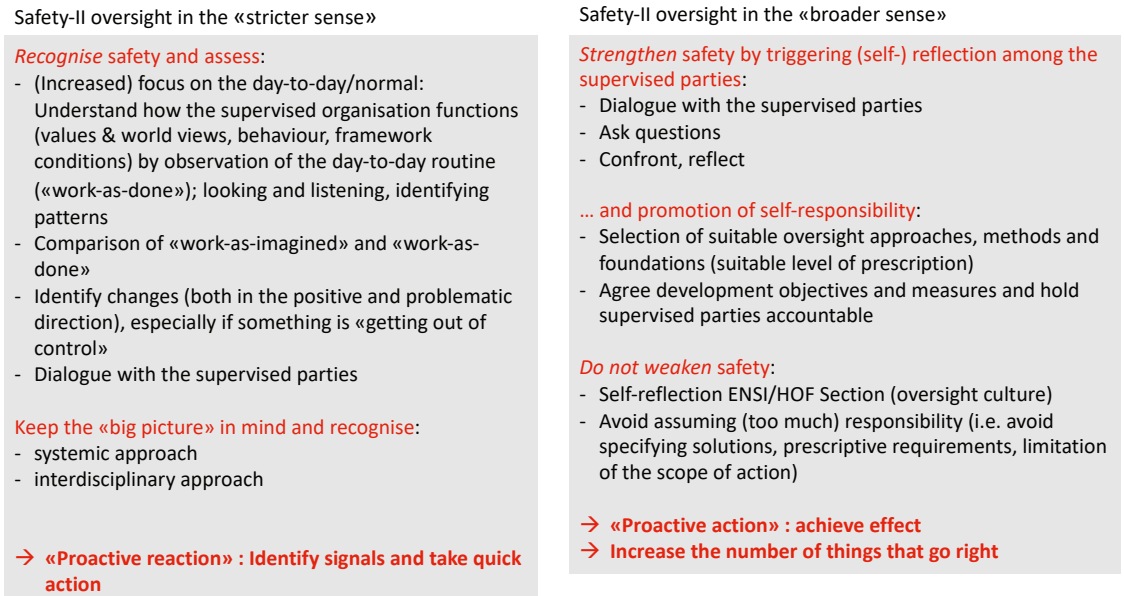
3.4.1 Basic considerations

In accordance with the above-mentioned distinction between oversight «in the stricter sense» and oversight «in the broader sense», a distinction is made here between Safety-II oversight «in the stricter sense» and Safety-II oversight «in the broader sense» (see Figure 8), although the distinction between the two types of oversight is not always a sharp one.

In the first case, it is a matter of identifying and assessing the safety status of the supervised organisations from the Safety-II point of view. The Safety-II focus is primarily on *understanding* the normal functioning of the organisation and the situational and context-related reality of day-to-day work («work-as-done») as well as in the comparison between «work-as-imagined» and «work-as-done». The aim is to *identify* at an early stage when performance variability and adjustments, which are a necessary part of daily activity, develop into a problem and then to intervene in a timely manner before interventions in line with Safety-I (prescriptive regulatory orders up to and including sanctions) become necessary («proactive reaction»).

The second case, on the other hand, is about strengthening the safety of the supervised parties through the use of appropriate oversight instruments, in particular by stimulating self-reflection in their organisations and fostering the assumption of direct responsibility («proactive action»). This approach also requires continuous self-reflection on the part of the inspectors in terms of the impact of their oversight on the potential and capability of the supervised parties to implement the Safety-II approach in their organisation, and on the suitability of oversight methods and content depending on the safety status of the supervised parties (see the blue arrows in Figure 7). A «reflexive oversight» approach is therefore necessary (see section 3.3).

Figure 8: Oversight with focus on Safety-II



Accordingly, the HOF Section derives the following higher-level requirements for its oversight using the Safety-II approach:

- Focussing not solely on compliance with the requirements of the regulatory framework and the internal regulations (evaluation, target-actual comparison, compliance-oriented oversight), but also on strengthening reflection and the direct responsibility of the supervised parties (performance-oriented oversight) (see section 2.2.1)
  - Strengthening the direct responsibility of the supervised parties by calling for the formulation of development objectives and measures
  - Holding the supervised parties accountable by asking for and providing feedback on the achievement of objectives and the effectiveness of measures

- Focussing not only on determining compliance with the requirements of the regulatory framework and internal regulations, but also on the understanding of the system in its context

- Focussing not exclusively/primarily on the «negative» (events, deviations, non-compliance with procedures etc.); increased focus on the *«positive»* or rather the *«normal»*
  - What is going right and why?
  - How does the work normally function?
  - How are/have problems been solved? (In contrast to: which problems exist/existed?)

- Focussing not exclusively/primarily on the «specified» (work-as-imagined); more focus on the *«actual»* (work-as-done)
  - How is day-to-day work actually carried out?
  - Which framework conditions define the work?
  - Which variabilities are apparent?

- Increased comparison of «work-as-imagined» and «work-as-done» by including representatives of both the «blunt end» and the «sharp end» in the oversight
  - To what extent do the facts presented by the management or the employees at the «blunt end» coincide with the actual situation and working methods of the employees at the «sharp end» (field experts)?
  - How can any discrepancies be explained? Which conditions make «work-as-imagined» more difficult?

- Reinforcing dialogue with the supervised parties

- Increased focus on the potentials of resilience and Safety-II among the supervised parties: the potential to react, the potential to monitor, the potential to learn, the potential to anticipate.

3.4.2 Methods for Safety-II oversight in the human and organisational factors area

The HOF Section uses different types of methods in its oversight, with which it pursues different purposes and deals with different topics (see Section 1.2). All oversight methods can also be used in accordance with Safety-II. While some of them are already conceived as Safety-II methods (in particular the instruments that are explicitly used to promote self-reflection), others must or may be deliberately enriched with Safety-II elements (namely those that primarily serve the purpose of the target-actual comparison and are therefore generally used as instruments for compliance verification and thus as Safety-I methods).

The *announcement* of the specific oversight activities to the supervised parties by the supervisory authority is of particular importance. Typically, specialist discussions and inspections are initiated by an announcement letter from ENSI, with which the topic and the reason for the announced oversight activity are communicated. The topic is frequently clarified by specific questions, which ENSI would like the supervised parties to answer. The nature of the formulation of these questions largely determines the nature and content of the specialist discussion or inspection, because it initiates corresponding internal preparation on the part of the supervised organisation. In the sense of the Safety-II approach, it is therefore of key importance to formulate the topics and questions in such a way that they initiate self-reflection among the supervised parties and strengthen the dialogue between the supervised organisation and the HOF Section.

For the *performance* of specialist discussions and inspections, the assembly of oversight teams (consisting of at least two members of the section or one member of the HOF Section and one member of a section from another specialist area), who have different backgrounds and experience and adopt different stances is recommended. For example, it may make sense for the specialist discussion or inspection to be jointly carried out by an employee in the section with in-depth knowledge of the organisation concerned, due to (many years of) oversight experience in the organisation to be supervised, and an employee with appropriate experience in another supervised organisation. While the former can integrate the findings from the relevant specialist discussion or inspection into the big picture of the organisation, the latter can bring in new impulses through their «external perspective» and at the same time gain insights for their oversight role in the organisations they primarily supervise (see also section 5.5).

Among other things, the oversight instruments described in section 1.2 and their possible use as part of a Safety-II oversight approach are examined below.

- *Specialist discussion promoting a dialogue on safety culture:* The dialogue on safety culture, which the HOF Section has conducted every three years since 2005 with the supervised parties (see /12/), can be attributed to the Safety-II approach. It follows the primary objective of triggering a self-reflection process among the supervised parties. In doing so, it supports the HOF Section in deepening its understanding of the culture and functioning of the supervised parties and in determining the congruence of this understanding with that of the supervised organisation. Moreover, it helps the HOF Section itself to reflect on its oversight and its impact on the safety culture of the supervised parties in that it receives feedback from the latter.
  - Therefore, with reference to these specialist discussions, in principle there is no need to adapt the process.
  - In the sense of a meta-reflection, the question of how resilience and Safety-II are (can be) implemented and practised by the supervised parties and embodied in the regulatory relationship between them and ENSI would be appropriate as a possible topic for conducting the dialogue.
  - The inclusion of a wider range of personnel categories (i.e. not only senior management executives or experts who explicitly deal with safety culture in their daily work) would allow all participants and ENSI to form a more

comprehensive and deeper understanding of the functioning of the overall system. This could be performed either as part of one discussion or as part of various separate discussions.

- *Exploratory specialist discussion:* Like the dialogue on safety culture, the exploratory specialist discussion serves to stimulate the self-reflection of the supervised parties and uses similar methods, although here topics that do not reference safety culture are also discussed.
  - The exploratory specialist discussion is suitable for confronting the supervised parties with the findings and results from the various oversight activities (inspections, specialist discussions, statements, permits, etc.) in the human and organisational factors area and the individual observations collected over a year, which, although not included in the systematic safety assessment of ENSI, do, however, in their entirety, indicate possible patterns or trends in the day-to-day functioning of the supervised organisations (see also /12/). The data collected and evaluated in this way by the HOF Section is reported back to the supervised parties in the form of aggregated findings and hypotheses and are then considered jointly with them. This feedback is an opportunity for the supervised organisation to compare its self-image with the external image of the supervisory authority and to reflect on its own day-to-day functioning. On the other hand, the discussion serves to deepen the HOF Section's understanding of the functioning of the supervised organisation and for the consideration of its oversight and its effect.
  - In addition to (low-level) deviations from an expected state and/or weak signals, which could potentially indicate deficiencies, the HOF Section's observations and findings should also include explicitly positive findings, which indicate the successful functioning of the organisation. In addition, specific attention should be paid to performance variability on a day-to-day basis, for example, to prioritisation of works or changing priorities.
  - In the qualitative evaluation and interpretation of the results of the oversight of human and organisational factors (e.g. from inspections and events, see /12/ and /13/), the focus should not only be on deviations and the need for improvement. Rather, assessments that match expectations («normality») and those that exceed expectation («good practice») should explicitly be included in the overall view as well.
  - Conducting exploratory specialist discussions involving field experts from the «sharp end» or groups of participants with diverse backgrounds allows valuable insights into the functioning of the supervised organisation to be obtained.

- *Information discussion:* This type of specialist discussion, which is used to obtain information and facts about actual issues (e.g. relating to events, projects or permits related to organisational or technical changes, etc.), can, depending on its alignment, concern both Safety-I and Safety-II aspects. For example, when dealing with events, it can be used primarily to understand why the undesirable event occurred and what can be done to prevent the event from reoccurring (Safety-I approach). Or it could (also) be used to understand the conditions under which the work in which the undesirable event occurred normally functions and why it has not occurred previously (Safety-II approach).
  - Information discussions should therefore also be used to collect as much information as possible about the normal functioning and the day-to-day performance of work and to understand which changing conditions and requirements influence the normal execution of the work. In addition, they can be used to make a comparison between the planned ideal-typical execution of the work («work-as-imagined») and the actual execution in practice («work-as-done»).
  - Information discussions should be conducted with different personnel categories. In doing so, the involvement of personnel from the «sharp end» should in particular be considered.
  - Information discussions do not necessarily have to be held in a meeting room, rather can also be held, at least in part, at in-situ workplaces. This makes particular sense if employees from the «sharp end» are involved. In addition, it enables a better understanding of «work-as-done» and the conditions and working circumstances influencing the work.
  - When involving employees at the «sharp end», discussions can be held with two employees at the same time. The resulting dialogue between the field experts can also support the acquisition of valuable insights into «work-as-done».
- *Inspection:* Within the scope of an inspection, compliance with the requirements of the regulatory framework (laws, regulations, guidelines) is checked. Inspections are carried out with regard to items unambiguously regulated in the regulatory framework. Typically, the focus is on deviations from the target state specified in the regulatory framework, whereby the regulatory framework usually takes no account of situation and context-related adaptations. Therefore, inspections are primarily a Safety-I instrument. For example, the HOF Section carries out annual inspections on the management system of the supervised parties. In doing so, it selects a process from the management system and checks whether it meets the requirements of the regulatory framework, in particular those of Guideline ENSI-G07 «The Organisation of Nuclear installations» (/9/). It also carries out annual inspections on the training of personnel in nuclear power plants, based on the requirements of Guideline ENSI-B10, Basic Training, Recurrent Training and Continuing Education of Personnel in Nuclear Installations» (/8/).
  - In the sense of the Safety-II approach, when defining the subject matter for inspections of the management system, in future it should be considered whether these can be carried out in two parts. Here, as in the past, in the first part, a target-actual comparison could be carried out between the processes and specifications in the

management system and the requirements from the regulatory framework («work-as-imagined»). In a second part, the implementation of the processes and specifications from the management system could be examined as directly as possible at the «sharp end» and with the involvement of the executing employees («work-as-done») using actual practical examples. The focus should be on the conditions under which the work is carried out and the personnel's adaptation efforts to successfully carry out the work, their approach to solving problems that arise, etc. Participating employees should primarily be seen as a «resource» and not as «risk factors».

- Within the framework of inspections on human and organisational factors, the scope is to be extended by involving different categories of personnel in different functions spread between the «blunt end» and the «sharp end» in the inspection.
- In addition, different methods should be used, for example interviews, workplace observations, plant walkdowns, etc. Both «work-as-imagined» and «work-as-done» aspects should be taken into account.

- *Event processing:* In the analysis and evaluation of (reportable) events with human and organisational aspects, the focus should not only be on the undesirable event (what went wrong), rather the positive aspects should also be taken into account. In addition to the clarification of the causes of the event and the definition of measures to prevent its recurrence (Safety-I), the reasons why the affected process normally runs smoothly (Safety-II) should also be considered.
  - When processing the human and organisational aspects of the event, the HOF Section (e.g. in the context of information discussions, see above) also asks which more serious consequences could be prevented and how, and which protection factors contributed to the ascertained outcome of the event.
  - Within the scope of event processing, the events should not (only) be considered individually (so-called «single loop learning»), but also in the context of other events (if possible also including non-reportable events or near misses) («double loop learning»).
  - In the context of their event analysis, the HOF Section also evaluate the follow-up actions in the human and organisational factors area defined by the supervised parties according to Safety-II criteria.
  - Should there be any requirements for actions in the context of event processing, these should be formulated in such a way that they stimulate self-reflection within the supervised organisation and strengthen its direct responsibility.

- *Safety-II forum across nuclear power plants:* The organisation of a reflection forum involving all or several supervised organisations on the Safety-II approach would contribute to strengthening dialogue and a common understanding of the significance and implications of the Safety-II approach between the supervised parties and the HOF Section.

In addition to the planning and implementation of individual oversight activities with the various oversight methods described above, joint learning from the experience gained as part of oversight within the HOF Section is an important part of a Safety-II-oriented oversight. Within the framework of a performance-oriented oversight (see section 2.2.1), exchange and joint reflection on the insights and findings gained are essential for the required understanding of the functioning of the supervised organisations in their respective current context, because a simple target-actual comparison based on clear criteria, as is the case with the Safety-I approach, is not possible.

In the sense of continuous improvement-oriented «reflexive oversight», the (joint) reflection on the effect of the oversight activity with regard to the safety and the safety culture of the supervised parties is also of great importance. The creation of «reflexive spaces» (see section 3.3) is therefore important not only in the interaction between the HOF Section and the supervised parties, but also within the Section itself.

Box 5: Digression: Requirements for the facilitation of conversations within the context of a Safety-II oversight approach

Discussions play a central role in the work of the HOF Section, in particular in the implementation of the described methods for Safety-II oversight, which are to a large degree dialogue-based. This means that employees in the HOF Section must also have specific skills in leading conversations, in addition to their technical competencies.

When heading any specialist discussion aimed at stimulating the self-reflection of the supervised parties, employees in the HOF Section often assume the role of a «facilitator». In this role, they guide the content of the discussions – by specifying the topic of the discussion by means of the announcement letter and the questions formulated in it (see section 3.4.2) – and they can also, at least in part or in certain types of specialist discussions, influence the process of the discussion and thus its course.

A central element in conducting reflection discussions is a questioning attitude to be adopted by HOF Section employees. The questions relating to reflection discussions are therefore not primarily aimed at the collection of information. Rather, by asking questions, the aim is to stimulate a collective thinking and learning process. The formulation of questions suitable for this purpose is therefore of great importance both in the preparation of the discussion with the drafting of the announcement letter and also throughout the course of the discussion.

The experience of the HOF Section shows that there are two important aspects of the facilitation of the discussion that must be considered during reflection discussions or that are a necessary precondition for achieving an open dialogue between ENSI and the supervised parties: 1.) the effort to achieve congruent and authentic communication, which means that the charisma and words of the interlocutors match each other and are perceived as credible; 2.) (active) listening. In addition to attentive and interested listening, this includes, for example, elements such as paraphrasing, that is, the repetition of what has been said in an alternative phraseology, the summarising of what has been said, questioning to check or deepen the understanding of what has been said, or also to provide feedback on what has been said.

4 Decision-making in emergency situations: influencing factors

After the earthquake in Japan in 2011 and the subsequent tidal wave that flooded the Fukushima reactor buildings, those in charge had to make many decisions. In a frame of uncertainty, time pressure and stress particularly the Fukushima Daiichi site superintendent had to be able to get all the information he required as the basis for his decisions. With the benefit of hindsight, it is now known that lots of information was incomplete or even misleading. Yet, nevertheless, decisions had to be made (/15/).

In complex emergency situations, similar to the situation at Fukushima, decision-making is influenced not only by situational factors, but also by factors that affect a single individual or an entire group. Before the influencing factors relating to deciding persons are examined in more detail, the external circumstances of emergency situations are discussed below[13].

In emergency situations, the responsible people are sometimes forced to make decisions – even if information is, at best, incomplete. Mistakes can occur if information has to be processed under time pressure or if too much information has to be processed. The brain is overloaded and tries to optimise between effort and benefit. As a result, thinking errors occur. Errors arise from the interaction between individual perception and situational characteristics (/3/).

In complex emergency situations, there is rarely enough time to gather and verify all information. The result is decision-making under uncertainty.

13 | The topic of decision-making is a very extensive and multifaceted research field (see for example /34/). The explanations contained in this report are limited to just a small part of it.

4.1 Decision-making under uncertainty (situational effects)

Situations in which difficult decisions need to be made under time pressure are often rather complex. Such situations often consist of extensive and networked issue threads that are linked together in unclear and dynamic ways, undetermined and uncertain in their impact (/7/). Therefore, handling uncertainty is an important requirement for people even in normal situations. Within an organisation, this uncertainty must be addressed at different levels. In complex and highly networked organisations, a system of rules helps because people acting locally cannot oversee all the consequences of their actions (/20/).

In complex decision-making challenges, situational factors set additional requirements on a person acting or deciding. These requirements include skills such as analytically registering details, but not losing sight of the overall picture, or choosing the right depth of information and the right extent of information. It also includes the ability to react to changing framework conditions and to conduct the entire decision-making process in a self-reflective manner (/3/).

There are several ways to reduce complexity and minimise the associated uncertainty (see also section 3.1). One of these is to reduce the scope of action by means of standardisation (/44/). The execution of emergency procedures is a method used in practice in which, in the event of design faults in nuclear installations, a flow diagram is processed according to clear input criteria in order to effectively combat the event and regain control of the installation. These regulations reduce complexity with clear procedures and clear criteria for responsibilities and decisions. Moreover, their application is practised regularly in exercises.

Another way of dealing with complexity is to cope with the uncertainty associated with complexity using flexibility and learning. Instead of limiting the scope of action to improve safety, the scope of action is increased. Deviations in day-to-day operations are perceived as learning opportunities and the application of rules is handled more flexibly (/44/). This path, which is based on learning and the integration of knowledge, shows how important an open attitude and personal experience gathered from day-to-day operations are. Deviations are perceived as an opportunity to learn something and not as a mean for pointing a finger at a guilty party. Such a path requires an open and prejudice-free handling of errors and near misses.

How the two approaches of limiting or extending the scope of action in organisations can be handled, was discussed in section 3.

4.2 Individual-related negative effects in the decision-making process

Even if in an emergency the situational circumstances were optimal for decision-making, there are person-related negative effects that can influence the decision-making capability of an individual or a group of people. Therefore, the focus should be in the following on the individuals or groups of people who make decisions. Relating to an individual, one cause of a negative influence may be the cognitive emergency response (/54/). A cognitive emergency response can occur when a person feels that their competencies are at risk and consequently they are subconsciously obliged to maintain the illusion of their own ability to act. Because of the subconscious process, it is practically impossible to recognise one's own cognitive emergency response.

In an emergency scenario, the person in charge is rarely completely isolated. Ideally, the person in charge is surrounded by an effective team. This begs the question of whether the cognitive emergency response of a single person can be compensated for by a group decision. Unfortunately, there are also effects associated with group configurations that can have a negative impact on decision-making. The decision of an individual is not necessarily improved if it is replaced by a group decision. Group decisions too have associated potential negative effects. For example, groupthink according to Janis (/33/). Groupthink arises when an attempt to achieve agreement dominates the decision-making process of a group of like-minded people with strong cohesion, such that people's perception of reality is impaired. Contributing elements to groupthink are a highly cohesive group of people isolated from alternative sources of information, with the leader clearly favouring one particular solution. In group discussions, these boundary conditions can create the illusion of one's own invulnerability and the rationalisation of one's own actions. Information that appears inconsistent or incomplete is downgraded or ignored. This process takes place both individually, in the form of self-censorship, as well as between individuals, in the form of pressure to achieve a consensus. The following section considers what should be taken into account in order to make good decisions.

4.3 People who make good decisions

Person-related negative effects can be prevented with respect to both groupthink and cognitive emergency reaction. Optimally they can be avoided altogether. This requires an attitude that can be trained and implemented during day-to-day operations. People who are not subject to cognitive emergency response are characterised by good self-management. They can withstand uncertainty and do not see their own competence threatened by a difficult situation. They can manage their own stress reactions well, even physical reactions, and allocate their attention to different aspects. Moreover, they can also handle their own feelings. If a person combines all these characteristics, then they possess a level of self-management that is suitable for handling an emergency situation, which should not lead to a cognitive emergency response. People with good decision-making skills communicate effectively and assume leadership and responsibility (/25/). The negative effects of groupthink can also be eliminated by a rational and balanced search for information with the information then used accordingly. Moreover, the person leading the group should not express their preferences in advance. Each member of the group should be able to express their thoughts and arguments independently of the others[14]. It is also useful to define procedural requirements for the decision-making process (/55/).

Making good decisions requires resources even during calm periods[15] and, optimally, a good deal of experience. Managers who have come through crises reported that they were helped by crisis expertise[16], self-management skills and experience in the crisis situation (/53/).

When making decisions in complex situations (including emergency situations), it is advisable to proceed as methodically as possible, even when time pressure seems to dominate the situation. To maintain control of accidents in nuclear power plants, technical systems start up automatically, and then well-founded checklists with decision trees are available. This wins valuable time. The time gained can be used to structure the decision-making process (/25/). Structuring elements are the formation of objectives, management of information, modelling, planning, decision-making and control (see box 6). After a decision, self-reflection should be carried out calmly and unhurriedly in order to trigger learning processes.

14 | In practical terms, for example, leaders of an emergency response team gather together the opinions of the various team members and then make their decisions.

15 | Resources here are defined as: personnel resources who can gather information; time resources to perform the information search and to be able to carry out an assessment/prioritisation; information sources from which to obtain the relevant information, etc.

16 | Crisis expertise: Knowledge about how first responder organisations (emergency services) function and act, and how the interfaces are managed.

Box 6: Structuring of the decision-making process according to Hofinger (/25/):

Unambiguous and clear objectives are drawn up during **objective setting,** with partial and intermediate objectives being defined. Contradictions should be recognised and balanced. It is important to set priorities and build consensus within the group (N.B.: remain aware of the effects of groupthink).

The **management of information** includes to determine what is not known yet. Additional needed information is still to be obtained and excess information rejected. The available facts must be evaluated and checks have to be made to see whether the depth of detail of the required information is sufficient.

The development of a common understanding is important for a team to provide a basis for action (**modelling**). Therefore, it is important to create an overview, to obtain a view of the interrelationships and to recognise critical points. Assumptions about causes and consequences must be made and forecasts created.

Steps in the course of time should be pre-defined and the situational characteristics considered as boundary conditions (**planning**). Where possible, branching points and alternative routes should be planned in advance. Possible friction points should be considered and buffers planned. The distribution of tasks within the team should be defined and interfaces between the actions of individual members planned.

For **decision-making** it is important to establish deadlines and pre-define decision-making mechanisms.

Timings and criteria for **checks** should be established and the four-eyes principle should be followed. Within the team, mutual checks are both an advantage and a challenge.

Self-reflection takes place after a decision, in peace and without any time pressure. Periods for reflection should be defined; mutual criticism within the team accepted and support should be used.

These recommendations for structuring decision-making processes can be more easily implemented in emergencies if (complex) decision-making processes have also been performed in day-to-day situations based on this pattern. In this way, helpful routines can be developed and unfavourable patterns identified and eliminated[17].

17 | In practice, different methods are used for structured decision-making. For example, among the operators of the Swiss nuclear power plants, the method FORDEC (Facts – Options – Risks – Decision – Execution – Check), or variants thereof, namely FOORDEC (Facts – Objectives – Options – Risks – Decision – Execution – Check) have become established for decision-making in situations where time is not the limiting factor.

4.4 Impact model of human performance under extreme conditions

The impact model of human performance under extreme conditions in Figure 9 exhibits diverse influencing factors. It also shows that changes in external influencing factors can lead to changes in the result of the decision and thus influences effective decision-making (/46/).

The impact model highlights factors that influence the decision-making process and actions under extreme conditions:

- Human capabilities (e.g. availability of skills, individual and collective stress management)
- Provision of the necessary infrastructure (taking into account human factor aspects): technical systems, work aids, tools, procedures, information etc.)
- Organisational aspects (responsibilities, roles, cooperation and coordination, communication, tasks and workflows, organisational culture).

If attention is paid to the reinforcing factors (Figure 9 shown in green), it becomes obvious that people who make decisions can have certain prerequisites that can be positively influenced by personnel selection, suitable staffing and training (personal and professional development). A supportive organisational environment plays an equally important role. In this respect, there is no simple recipe for becoming a good decision-maker. Essential is the interaction of organisational processes and the practiced attitude, which is reflected in the organisational culture. These factors allow employees to develop their abilities to make good decisions in emergency situations.

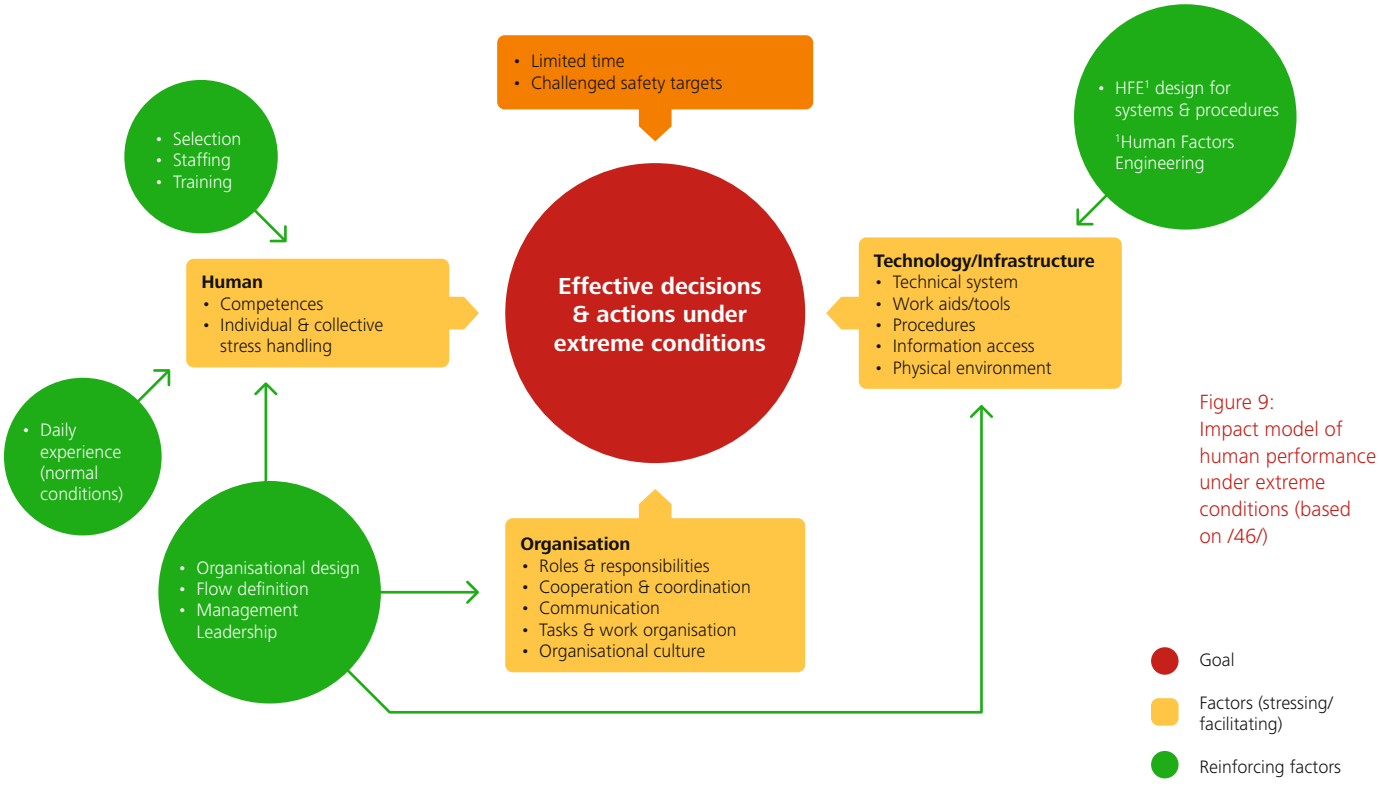


Figure 9: Impact model of human performance under extreme conditions (based on /46/)

4.5 Oversight relating to the topic of decision-making

The topic of decision-making is included in the oversight of the HOF Section in a variety of ways. In doing so, the focus of oversight is primarily on the behaviour of actors in the «work-as-done» visible in different contexts, and on the conditions created and provided by the organisation, instruments and guidelines for the decision-making by the players. The assessment of the personality-related aspects of successful decision-makers are difficult to measure directly, thus not in the focus of oversight.

Decision-making and taking responsibility go hand in hand. Responsibility in the area of nuclear safety lies in the first instance with the operator of a nuclear installation and the licence holder respectively (Art. 22 para. 1 NEA /36/) (see section 2.2.1). In the licence holder's organisation, decisions are structurally anchored at various levels of the organisation and are implemented in the process organisation. Decisions are visibly anchored in process sequences in which responsible function owners are appointed. Guideline ENSI-G07 (/9/) specifies the legal requirements.

The supervisory authority reviews the formal requirements specified by the licence holder's organisation. This review normally takes place as part of an inspection of a specific object. References to decision-making processes can be found in documents, such as decision-making records, review signatures or the like.

In specialist discussions (see section 1.2), the authority addresses specific topics, including decision-making processes and the influences thereon.

In emergency exercises observed by the authorities, especially in respect of the work of the emergency team, as well as in the practical licencing exams on the plant simulator, the observation of decision-making is one evaluated category amongst others.

In the human and organisational factors area, permit applications for nuclear installation backfit projects require a programme to take account of human and organisational factors (HOF programme). The process steps described and the iterative procedure in the various phases of backfit projects provide information on the experienced process of decision-making in the day-to-day project routine of the supervised parties. Something anchored in day-to-day routine can subsequently be more easily accessed under emergency conditions.

Where events occur, the topic of decision-making is, if necessary, retrospectively analysed and evaluated by the operating organisation. Here, the feedback of findings to the organisation is of central importance. Knowledge gained from events outside the organisation (evaluation of external operating experience) is also an important source of improvement (/9/).

4.6 Conclusion

The foundation for good decisions can be laid with structured decision-making processes, training courses and an open attitude to information. If extreme emergencies occur, purely organisational measures in the form of standards and rules no longer suffice. If extreme emergencies occur, decision-makers are characterised by an awareness of themselves and their own limits so that they can deal with it mindfully. An additional necessary boundary condition is the possibility of relying on a team in which mutual trust prevails and which implements clear directives in a targeted manner and reacts flexibly to new turns of events (see also section 3.1).

The oversight must focus primarily on the observable or inferable expression of these characteristics of effective decision-making in the manner of behaviour, processes, specifications, and products. In varied ways, this was and is the case in the oversight of the HOF Section. For this reason, no additional specific regulatory measures have been derived.

5 A digression concerning resilience: an input from civil aviation

A resilient organisation strives for alertness and flexibility so that it can adapt at any time to the prevailing situation and is therefore prepared for unexpected situations. On the one hand, the following digression on civil aviation shows how the skills and abilities of cabin crew members of an airline are trained so that the crew is prepared for the unexpected. On the other hand, raising of awareness of the unexpected in the day-to-day routine is described.

How Erik Hollnagel's four potentials for resilience (/29/, see section 3.1) take effect and from which aspects of civil aviation safety management nuclear oversight can learn, are presented at the end of this digression on resilience.

5.1 Development and training: process adaptation, improvisation and decisions

In the field of civil aviation, the one-month emergency training includes, among other things, topics such as technical and medical aspects, emergency equipment, procedures, evacuation methods and crew resource management CRM (situation awareness, communication, decision-making, adaptability and flexibility, leadership and assertiveness). Further three-day aircraft-specific training courses, a two-month «on-the-job» induction period, annual two-day recurrent training courses and training in the simulator contribute to practising existing procedures and overcoming fears, increasing perception and positively supporting and strengthening creativity and flexibility. The simulations focus on situations that require process adaptations, improvisation and quick decision-making.

An example of a fire fighting training sequence illustrates how these skills are practised in civil aviation. In a training building, various situations are simulated with different smoke sources and types of fire, which are faced by crew members from different occupations: sometimes alone, sometimes in pairs, they have to extinguish fires and look for and identify sources of smoke. Dependent on the scenario, the familiar emergency equipment from the aircraft is available to solve the task. To be able to instil a capability for improvisation, the emergency equipment is only partially available or functional. In this way for example, the improvised use of uniform jackets, blankets, newspapers, liquids, etc., is practised for the purpose of fire-fighting. Moreover, in the aircraft simulator, the crew members are also confronted with scenarios in which, for example, smoke develops in the cabin – the situation then requires an emergency landing with subsequent evacuation under complicated conditions.

5.2 From flight preparation to final destination: raising awareness of the unexpected in the day-to-day routine

Gathering information: Good flight preparation begins with each individual still at home. Alongside preparations that affect the flight itself and the crew, information is obtained from the intranet and Internet about the destination. This information extends from orientation on the political situation through behaviour recommendations and infectious diseases and up to emergency telephone numbers on the ground.

Exchanging, learning and consideration of information: A 30-minute briefing takes place before every flight. It allows the crew to briefly introduce themselves, to assign tasks and positions, and to exchange information about the passengers, crew members and the flight. There is also a topic for discussion with reference to safety.

During the round of introductions, information about special training, capabilities and acquired skills that may be relevant to safety is also exchanged: information such as membership of a local fire brigade, a second job as a paramedic, basic psychological training or special language skills that are relevant for colleagues so that they know what skills they can draw upon in an unexpected situation.

Information about passengers (such as disabilities, animals such as guide dogs, children travelling alone, people who are being deported or denied entry, flight marshals who are accompanying the flight undercover) helps the crew to get an idea of the risks and resources present on board and to define the responsibilities of the crew members.

Information about the areas being crossed, such as water, mountains, desert or jungle, makes crew members aware of what they might encounter in an intermediate or emergency landing.

The safety-related topic that is also discussed during the briefing, can be specific to the upcoming flight, or focus on an emergency procedure, or an experience of a crew member: e.g. the protection factors identified during a successful participation in an emergency landing, the reaction to a medical incident or what emergency equipment is important in the event of ditching. The discussion of a safety-relevant topic applicable to day-to-day work is a beneficial learning opportunity for the crew members that has practical relevance. At the same time, the acquired knowledge, procedures and handling of equipment are repeated.

Resources for safety checks: Each crew member uses a checklist to check their station together with its emergency equipment: For example, does the megaphone work? Is there an axe with fire gloves? If equipment is missing or malfunctioning, maintenance is contacted. The safety check gives crew members an overview of the equipment they have and where it is stored in the particular aircraft type, so that they can act quickly in the event of an incident.

Screening: Boarding, including welcoming passengers and assistance with finding a seat and luggage storage, is also an opportunity to monitor the behaviour of passengers. In the event of peculiarities, an attempt to initiate a dialogue is made in order to identify possible difficulties such as fear of flight, a medical problem or a strong influence of alcohol, and to provide support or help if necessary.

«One minute of silence»: Immediately before take-off and landing, the crew members receive a sign from the cockpit for «one minute of silence»: Before the most delicate phase of any flight, crew members run the procedures through their heads in case anything unusual were to happen (for example, in the event of a difficult aborted take-off or engine damage). Here the following considerations are focussed on:

- Is my seat position correct so that I am protected in the event of an aborted take-off?
- What is the surrounding area like? Are we landing or starting over water?
- What are the evacuation orders for ditching?
- Which passengers near me can assist me if necessary?
- What is the name of any colleagues in my vicinity?
- What commands should be shouted into the cabin if the door sticks?
- What emergency equipment do I take with me?
- Where are unaccompanied children, passengers with disabilities, etc. sitting?

Safety awareness and communication: During the flight, peculiarities such as strange odours and noises as well as information from passengers is followed up and the cockpit is informed. To ensure the pilots have an idea of the situation in the aircraft cabin, good communication with the cabin crew is very important for safety.

Safety awareness, all times and everywhere: After landing, passengers feel the urge to leave the plane as quickly as possible. However, due to the many near misses and accidents that occur on the airport ground, it is important that they remain seated with their seat belts fastened until the park position is reached. Only when the engines are shut down and a stairway or the passenger boarding bridge is docked, may pilots give the okay to open the doors. It is only just prior to this that the cabin crew is asked to disarm the evacuation slides. Once again, this procedure requires the full attention of the crew. Opening the doors prior to the okay of the pilots could have fatal consequences for the ground personnel because the slides would still be armed and would deploy. In spite of the exertion of the flight and possible fatigue, safety awareness is required right up to the end of the flight.

5.3 The four potentials for resilience

The four potentials for resilience (see section 3.1) can be explained below with examples drawn from civil aviation:

- *The potential to RESPOND:* «Knowing what to do» is practised in training, simulations and improvisations and consolidated in day-to-day work; daily briefings contribute to being well prepared and fully aware.

- *The potential to MONITOR:* «Knowing what to look for»; the flight preparation, entry into the airport premises, briefing room and finally the aircraft – all ensure crew members are sensitised to the surroundings, events, people, sounds and smells, they consciously perceive them and take reported anomalies seriously. This sensitised perception is practised and internalised in training and in the simulator.

- *The potential to LEARN:* «Knowing what has happened»; personal experience in daily work, the exchange of positive and negative experience in briefings and annual training sessions, in which new findings are addressed, implemented and acquired, as well as, for example, experiences from other airlines. All this leads to both single and double-loop learning and will be implemented in the organisation.

- *The potential to ANTICIPATE:* «Know what to expect»; with the learned procedures, training, simulations and improvisations, flight preparation and knowledge of the resources and challenges of the current situation, as illustrated in the «one minute of silence» example, as well as increased perception of external influences, crew members are prepared to react, decide, act and improvise.

5.4 Reflection – learning from the special features of civil aviation

In addition to the cooperation between changing crew members, special features of civil aviation include the varying daily working hours, rotations, working positions and destinations with constantly changing passengers – all of which demand a high degree of flexibility and adaptability. To get to know the team, the crew members have a single half hour briefing. Techniques and procedures that support safety are used in an intuitive manner, such as the use of the phonetic alphabet, the four-eyes principle, cross-checks, STAR («Stop – Think – Act – Review»), etc. An ever-changing team make-up is also conducive to identifying personal blind spots. Another feature that contributes to safety is the briefing, in which the crew members exchange ideas about negative and positive examples from day-to-day work, gather new insights and focus not only on the factors that led to an event, but also on the protection factors, that guided the event towards a positive outcome. These may be technical, organisational and/or human factors.

Crew members, with their implicit and explicit knowledge, experience, training, alertness, situational awareness, flexibility and creativity, their decisions and the inherent scope of action they need in order to adapt their actions and behaviour, are considered as safety factors prepared and qualified to respond to unexpected situations.

5.5 Reflection – conclusions for the oversight of the HOF Section

The oversight of the HOF Section could benefit from a more diverse team composition in its inspections and specialist discussions, as is the case in civil aviation. In doing so, it could break up or enrich any deadlocked patterns and prevent blind spots. It is important to continue to support and strengthen the involvement of inspectors from other sections in the oversight activities of the HOF Section. Varying interdisciplinary cooperation not only extends the section's own horizon, but also promotes an integrated system view, taking into account the systemic approach (see section 2.2).

As with the briefing prior to a flight, an increased emphasis could be placed on positive examples during preparatory discussions and the debriefings following the specialist discussions or inspections of the HOF Section. This would be in the context of learning from experience and the Safety-II approach (see section 3.2).

Safety-II aspects could also be increasingly considered in event processing as is the case in civil aviation briefings. Currently, processing focuses on the contributing factors that led to an event and the resulting actions. According to Safety-II, the protective factors that prevented an event with more serious consequences must also be examined, acknowledged and strengthened. These protective factors can be of a technical, organisational and/or human nature (see section 3.4.2).

Exchange of experience, and cooperation with the supervisory authorities and institutions of other safety-related industries stimulates a change of perspective, enables learning from the experiences of others, benefits both organisations and boosts their resilience. Consolidation of this exchange should continue.

6 Closing words

This report represents both an «output» and an «input» for the HOF Section. On the one hand, it is the conclusion of the three-part series of reports on the human and organisational factors of the Fukushima Daiichi reactor accident. It covers the insights of the HOF Section since the accident in March 2011 and the experience gained for oversight in the human and organisational factors area. On the other hand, it is the starting point for further reflection and the development of the oversight of the section against the background of these insights and the current state of the safety sciences.

The HOF Section will develop an action plan for the short, medium and long-term implementation of the topics, methods and approaches for future oversight presented in the individual sections of the report.

The derived implications for the oversight of the HOF Section concern, on the one hand, topics that are dealt with in the framework of oversight and on the other hand, oversight approaches and methods that are to be applied in the oversight. These topics, approaches and methods are based on the two basic concepts of the systemic approach and the Safety II approach and resilience, which are themselves anchored and established in the safety sciences. Official investigations into the accident at the Fukushima Daiichi nuclear power plant identified these concepts as the basis for lessons and recommendations for the further development of nuclear safety at nuclear installations across the world.

As the approaches and methods based on the traditional Safety-I approach have been proved and established over many years, they have not been discussed in this report. Rather, the object of this report is the less well-established approaches and methods for oversight based on the Safety-II approach.

Implications for the approach to oversight in the area of human and organisational factors

Against the background of the systemic approach and the concepts of resilience and Safety-II, a number of implications for the regulatory approach of the HOF Section have been derived. Accordingly, a stronger focus on performance-oriented oversight, in contrast to purely compliance-oriented oversight, is proving to be effective (see in particular section 2.2.1). The focus is on dialogue between the supervisory authority and the supervised organisations and the promotion of self-reflection and strengthening of direct responsibility among the supervised parties through appropriate regulatory activities. Furthermore, the focus of the oversight should be on understanding the normal functioning of the supervised organisation and the day-to-day execution of the work and not exclusively on the search for negative events, deviations from target specifications and the notions of ideal-type work and procedures (see in particular sections 3.3 and 3.4).

Nonetheless, it is important to bear in mind that it is not sensible to apply a standardised and ever unchanging oversight strategy. This means that, in the sense of a «responsive regulation», different regulatory approaches must be applied depending on the situation, context, culture or safety performance of a supervised organisation. These can escalate over a continuum which extends from oversight based on dialogue, conviction, and extensive direct responsibility and self-regulation up to increasingly demanding and prescriptive interventions by the supervisory authority which culminate in strict sanctions (see in particular section 2.2.1).

Implications for the oversight methodology

Oversight based on the systemic approach and Safety-II requires methods based on dialogue and reflection. Therefore, the HOF Section checked whether and how it could appropriately develop further its oversight methods based on discussions (see section 3.4.2). The specialist discussion promoting a dialogue on safety culture as well as exploratory specialist discussions should be viewed as prototype discussion-based methods for the Safety-II approach. By contrast, information discussions and inspections must be explicitly supplemented with Safety-II elements. This requires, for example, the formulation of questions and discussion techniques, which are suitable for strengthening the (self-) reflection and direct responsibility of the supervised parties. Safety-II aspects can also be used to supplement event processing, for example, by not only focusing the analysis on the causes of an adverse event, but also highlighting the factors that prevented a worse course of events or the factors that contribute to the normal smooth running of the affected process. Finally, a forum across power plants could strengthen dialogue and exchange between the supervisory authority and the supervised parties as well as between the supervised parties themselves.

Learning from other industries is important not only for the operators of nuclear installations, but also for the supervisory authority itself. For this reason, this report looks at methods for strengthening resilience in civil aviation and draws conclusions from them for oversight, for example, in terms of strengthening interdisciplinary cooperation and the systemic approach by making appropriate arrangements for oversight teams or by organising briefings and debriefings that promote learning (see section 5.4).

Identified oversight items for oversight

Based on identified topics used to check the application of the systemic approach in the context of the continuous improvement of the management system, oversight items have been identified, to which the HOF Section will devote special attention or to which is has already devoted special attention in the past (see section 2.2.2). These regulatory items are located at the strategy, process or working level of the HTO systems under consideration and relate to topics such as the purpose, vision and strategy of the system, the system boundaries and the external context of the system, the processes and activities for effective and safe operation, the effectiveness of measures and the continuous improvement of system robustness and resilience.

Another oversight item, which is dealt with within the scope of oversight, relates to decision-making in emergency situations. Decision-making is already the subject of numerous oversight activities of the HOF Section. Further topics may arise from oversight practice (see section 4.5).

A catalogue of questions is also to be drawn up as a working tool to support the oversight work. This will contain appropriate questions for the topics covered in this report, but also, where applicable, for other oversight items in the area of human and organisational factors, and will be drawn upon during the preparation for corresponding oversight activities.

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8 Endnotes

[i] «The accident at the Fukushima Daiichi NPP was a surprise outside the boundaries of the basic assumption of the key stakeholders, meaning the stakeholders had not been able to imagine that such an accident could occur. From this, the lesson learned for the international nuclear community is that the possibility of the unexpected needs to be integrated into the existing worldwide approach to nuclear safety» ([31], p. 146).

[ii] «NISA's oversight and regulatory activities were often based on compartmentalized thinking, i.e. it did not sufficiently address issues in a broad, systemic manner, considering all aspects relevant to safety (…). Particular emphasis was placed on technical issues, compared with operational aspects and human and organizational factors (…)» ([31], p. 130).
«In addition, the regulatory bodies were less disposed to learning from international experience (…) showing a clear tendency for isolation (…), frequently arguing that lessons learned and approaches from other countries were not applicable to Japan» ([31], p. 130).

[iii] «A systemic approach to safety needs to be implemented by all participants and in all types of activities within the nuclear power programme and throughout the entire life cycle of nuclear installations, including review services offered by international organizations. As was shown by the analysis, in Japan, nuclear installations, TEPCO and NISA primarily focused on the technical aspects of nuclear safety. A systemic approach to safety implies that all stakeholders, besides the technical factors, take comprehensively into account the human and organizational factors, including safety culture, to build resilient capabilities» ([31], p. 144).

[iv] «The basic idea of responsive regulation is that governments should be responsive to the conduct of those they seek to regulate in deciding whether a more or less interventionist response is needed» ([2], p. 29).

[v] «… with regard to nuclear emergency preparedness, it was not necessary to anticipate an accident that would release enough radioactive material as to actually require protective actions, since (they believed) rigorous nuclear safety regulations, including safety inspections and operation management, were in place in Japan» ([45], p. 137).

[vi] «Resilience is an expression of how people, alone or together, cope with everyday situations – large or small – by adjusting their performance to the conditions. An organisation's performance is resilient if it can function as required under expected and unexpected conditions alike (changes/disturbances/opportunities)» ([29], p. 14f.).

[vii] «Resilience competencies and resources have to be developed well in advance within organizations to help personnel to quickly and flexibly adapt to new situations, to develop new solutions for blind spots – in other words: to be resilient in unexpected situations» ([31], p. 146).

[viii] «The signature of a high reliability organization (HRO) is not that it is error-free, but that errors don't disable it» ([58], p. 95).

[ix] «Knowing what to do or being able to respond to regular and irregular changes, disturbances and opportunities by activating prepared actions, by adjusting the current mode of functioning, or by inventing or creating new ways of doing things» ([29], p. 26).

[x] «Knowing what to look for or being able to monitor that which affects or could affect an organisation's performance in the near term – positively or negatively. (In practice, this means within the time frame of ongoing operations, such as the duration of a flight or the current segment of a procedure.) The monitoring must cover an organisation's own performance as well as what happens in the operating environment» (/29/, p. 27).

[xi] «Knowing what has happened or being able to learn from experience, in particular to learn the right lessons from the right experiences. This includes both single-loop learning from specific experiences and the double-loop learning that is used to modify the goals or objectives. It also includes changing the values or criteria used to tailor work to a situation» ([29], p. 27).

[xii] «Knowing what to expect or being able to anticipate developments further into the future, such as potential disruptions, novel demands or constraints, new opportunities or changing operating conditions» ([29], p. 27).

[xiii] «An integrative framework should also accommodate the positive, as well as the 'negative', aspects of resilience: the processes of improvement, adaptation and innovation as much as the management of the adverse impacts and crises that are often viewed as the prime trigger of resilience» ([43], p. 127).

[xiv] «It is not just about being able to recover from threats and stresses, but rather about being able to perform as needed under a variety of conditions – and to respond appropriately to both disturbances and opportunities» ([29], p. 15).

[xv] «In general, Safety-II is about learning from things that go right and improving resilience, where Safety-I is about learning from things that go wrong and improving compliance» ([41], p. 1).

[xvi] Comparison of the characteristics of Safety-I and Safety-II (/28/, p. 147)

	Safety-I	**Safety-II**
Definition of safety	As few things as possible go wrong.	As many things as possible go right.
Safety management principle	Reactive, respond when something happens, or is categorised as an unacceptable risk.	Proactive, continuously trying to anticipate developments and events.
Explanation of accidents	Accidents are caused by failures and malfunctions. The purpose of an investigation is to identify causes and contributory factors.	Things basically happen in the same way, regardless of the outcome. The purpose of an investigation is to understand how things usually go right as a basis for explaining how things occasionally go wrong.
Attitude to the human factor	Humans are predominantly seen as a liability or a hazard.	Humans are seen as a resource necessary for system flexibility and resilience.
Role of performance variability	Harmful, should be prevented as far as possible.	Inevitable but also useful. Should be monitored and managed.

[xvii] «The central theme of centralized control is 'plan and conform', while the central theme of guided adaptability is 'plan and revise'» ([49], p. 11).

[xviii] «Managers, safety professionals and frontline workers need to determine when, for a given context, the safe course of action is to comply with standardized practices, and when the safe course of action is to adapt» ([49], p. 11).

[xix] «Poorly designed and implemented regulation can therefore dramatically reduce the attentional resources, local authority and capacity for flexibility on the front line of health care organisations. That is, poor regulation can reduce organizational capacities for resilience» ([42], p. 116).

[xx] «Regulatory technologies that aim to support centralized and standardized control of behavior appear immediately at odds with the emphasis that most models of resilience place on local innovations, flexibility, improvisation, adaptability, problem solving, vigilance and trial-and-error learning» ([42], p. 115).

[xxi] «With this much riding on compliance, organisations can become overly focused on meeting regulatory requirements merely to manage the risks of regulatory sanctions (…), at the expense of actually managing the underlying risks to quality and safety that the regulations are intended to address – so called 'secondary risk management'» ([42] p. 116).

[xxii] «But the concepts of regulation and Safety-II are actually quite similar; both are about making sense of situations in the context of their social dynamics» ([41], p. 2).

[xxiii] «One could call this a move from regulatory oversight to regulatory insight» ([41], p. 4).

[xxiv] «We conceptualize reflexive spaces as physical or virtual platforms in which reflexive dialogical practice occurs between people. The reflexive dialogical practice is key in learning processes, because it bridges tacit and explicit knowledge. Reflexive spaces can bring people together to reflect on current challenges, adaptations, and needs in daily work practice. Reflexive spaces are forums inviting accountability and feedback on concrete practices and the effects they generate. They are collective in the sense that they mobilize experiences of relevant actors within and outside healthcare practices. Accountability within such spaces is generative in the sense that it adds to learning rather than curbing it» ([60], p. 2).

[xxv] «The goal of this approach is to leave the responsibility for safety as much as possible with the organization and management itself, while checking the capability and willingness of the organizations to manage. 'Trust, but assess trustworthiness' is key and the established reflexive spaces depend on these characteristics of trust, responsibility, and engagement to leverage resilience into regulation and management» ([60], p. 2).

[xxvi] «Only if an open dialogue between operator and regulator is established, can the operational flexibility which lies at the heart of resilience be effectively realized» ([21], p. 65).

[xxvii] «The task of the regulatory body is highly demanding and entails the duty of continuously challenging and questioning the basic assumption held by the industry it regulates and by itself. This implies high demands on the regulator's self-reflecting capability to put its own role and its impact on nuclear safety and on the collective perception of nuclear safety under constant self-scrutiny» ([31], p. 144).

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