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Review of methodologies for analysis of safety incidents at NPPs

Final report of a co-ordinated research project 1998–2001

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FOREWORD

The safe operation of nuclear power plants around the world and the prevention of incidents in these installations remain key concerns for the nuclear community. In this connection, the feedback of operating experience plays a major role: every nuclear power plant or nuclear utility needs to have a system in place for collecting information on unusual events, whether these are incidents or merely deviations from normal operation. Reporting to the regulatory body of important events and lessons learned is normally carried out through the national reporting schemes based on regulatory reporting requirements. The most important lessons learned are further shared internationally, through, for example, the Joint IAEA/NEA Incident Reporting System (IRS) or the event information exchange of the World Association of Nuclear Operators (WANO).

In order to properly assess the event, an adequate event investigation methodology has to be applied, which leads to the identification of correct root causes. Once these root causes have been ascertained, appropriate corrective actions can be established and corresponding lessons can be drawn. The overall goal of root cause analysis is the prevention of events or their recurrence and thus the overall improvement in plant safety.

In 1998, the IAEA established a co-ordinated research project with the objective of exploring root cause methodologies and techniques currently in use in Member States, evaluating their strengths and limitations and developing criteria for appropriate event investigation methodologies. This report is the outcome of four years of co-ordinated research which involved 15 national and international research organizations.

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SUMMARY

The purpose of this co-ordinated research project (CRP) was to research various event investigation methodologies suitable for use by nuclear power plants and regulatory bodies. It was considered that an investigation of methodologies for incident analysis would be most efficiently performed if it were divided into the following three main topics:

— to identify the characteristics of methodologies suitable for the investigation of safety events;
— to conduct a review of the methodologies available to the research participants for the analysis of event root causes and finally;
— to examine the effectiveness of operating experience feedback from safety events that had occurred at plants and had been subject to formal investigation.

Clearly an important initial step is to determine under what circumstances an in depth investigation of a safety event is necessary. All safety significant events and all events which the operator believes would benefit the long term safe operation of the nuclear power plant need to be subject to in depth investigation and analysis. Events of lesser significance need to undergo investigation and analysis of varying degrees depending on the complexity of the event. In every case, the scope of the event investigation should encompass people, technology, organizational factors and the environment.

For single event analysis, the methodologies need to consider human factors affecting safety. In addition, they have to be practical and flexible enough to meet the needs of the nuclear power plant and as forward looking in their findings as possible. The methodologies need to follow a logical and structured process; they are to be used only by trained team members.

Event aggregates, namely groups of prior events with common aspects or themes, may also warrant investigation. For the review and analysis of event aggregates, the event trending and analysis in the methodologies should be based on clearly defined, high quality data sets, national and international data should be accessible and staff who use suitable methodologies and have been trained in statistical analysis are desirable.

To ensure that the most suitable methodology/technique is chosen, it is appropriate to first review and evaluate available techniques and then to adopt, modify or propose novel techniques to suit the circumstances prevailing in the organization. Studies have previously been performed in this domain. Nonetheless this CRP made the following observations:

— ASSET remains an established methodology in use in several countries;
— HPES is widely used throughout the nuclear industry;
— MORT is not widely used but is considered to be a viable option;
— fault tree analysis is extremely useful and is integral to many other methodologies;
— several other methodologies were developed as a result of this CRP and enjoy limited country based use. These include SOL-VE (Germany), PRCAP (Hungary), AEB (Sweden) and PSA – Based Analysis (Finland).

The work performed in the framework of this CRP focused primarily on ASSET, HPES and MORT; the strengths and limitations of these different methodologies are identified along with the extent of their current use.

It must be noted that, although the ASSET service previously provided by the IAEA is being replaced by a new service known as PROSPER (Peer Review of Operational Safety Performance Experience), the ASSET methodology will continue to exist. However, further training on ASSET will not be undertaken by the IAEA. PROSPER involves self-assessment and peer review of the use of operating experience, but it is not an event investigation methodology.

The CRP also identified the value of performing low level event reporting and the trending of the low level event precursors to proactively identify weak defences and situations likely to lead to errors before they contribute to consequential events.

Corrective actions result from the event investigation. Indeed, an effective corrective action will:

— prevent recurrence by addressing the root causes and flawed defences;
— fall within the capability of the utility to implement in a timely manner;
— allow the utility to meet its primary objective — the safe and reliable production of power;
— not have any detrimental effect on other plant systems nor affect human performance;
— be clearly stated, unambiguous and recognized by the acting party.

Corrective actions must also be prioritized according to:

— safety significance;
— recurrence of the event;
— injury to personnel;
— harmful effects to the environment;
— damage to the plant.

Having identified a suitable event investigation methodology, trained the necessary personnel in its use and applied the methodology to an actual event, it is then necessary to evaluate the effectiveness of the resulting corrective actions and the effectiveness of the operating experience feedback to ensure that recurring events are prevented.

To ensure the effective implementation of the event investigation process, top level management commitment is vital, especially with regard to the Operational Experience Feedback (OEF) process, namely, those actions arising from screening of both internal and external event reports. A process of accountability also aids in ensuring that actions arising from shared operating experience are implemented in a timely manner.

The identification and efficient implementation of an effective event investigation methodology contributes to the picture of a healthy safety culture.

INTRODUCTION

The assurance of the safe operation of nuclear power plants (NPPs) around the world and the prevention of incidents in these installations remains a key concern of the nuclear community. In this connection, the feedback of operating experience plays a major role: every nuclear power plant or nuclear utility needs to have a system in place for collecting, analysing and disseminating information on unusual events, whether these are incidents or merely deviations from normal operation. Reporting to the regulatory body of important events, and lessons learned, is normally carried out through the national reporting schemes based on regulatory reporting requirements. The most important lessons learned are then shared internationally, through, for example, the mechanisms of the Joint IAEA/NEA Incident Reporting System (IRS) and the event information exchange of the World Association of Nuclear Operators (WANO). There is now also a realization that valuable safety information can be gained by limited analysis and trending of 'low level events', that is, events which have no safety consequences but are worthy of recording for the lessons they impart.

It is extremely important that all involved parties, and specifically both operators and regulators, should possess and implement an adequate event investigation programme and that a multidisciplinary group of trained investigators exists within the respective organizations. It is also vitally important that senior utility and senior regulatory managers are fully supportive of the programme and allocate adequate, dedicated resources to operating experience activities, including the event investigation process of the programme. It has been identified that it is imperative that comprehensive personnel training in the chosen event investigation method is undertaken to ensure a successful event investigation process.

In order to objectively assess events, an adequate structured event investigation methodology has to be applied, which leads to the identification of appropriate root causes by which relevant corrective actions are established, implemented and closed out and corresponding lessons learned and circulated to interested parties. The primary goal of event investigation is the prevention of events and their recurrence and in so doing achieving an overall improvement in nuclear safety.

In 1997, the International Atomic Energy Agency (IAEA) initiated a Co-ordinated Research Project (CRP) to investigate the methodologies utilized for event investigation and analyses. Various organizations were invited to participate in this CRP and fourteen such organizations were selected by the IAEA, according to their respective research proposals, to undertake research on the objectives of the CRP which were:

(a) To develop a spectrum of event investigation methodologies/techniques for particular application areas emphasizing the multiple cause determination concept with corresponding definitions and classifications of direct and root causes.
(b) To review and analyse existing event investigation methodologies and techniques, determine their applicability areas and evaluate their strengths and limitations.
(c) To explore feedback of operating experience, especially on event investigation (root cause) methodologies and techniques in current use.

Meetings for the participants of this CRP were organized by the IAEA and held in Vienna, Austria on 20–24 April 1998; Edinburgh, Scotland on 11–15 October 1999 and Cape Town, South Africa on 5–9 March, 2001. The objectives of the meetings were to present the work which was ongoing at the participating organizations and to discuss future directions of the CRP.

In addition to interim progress reports which were submitted to the IAEA with respect to the various individual CRP research projects being undertaken by the participating organizations, each of the participants at the meetings gave presentations on the status of incident analysis within their respective organizations. These presentations are contained in separate IAEA Working Material documents.

1. CHARACTERISTICS OF APPROPRIATE EVENT INVESTIGATION METHODOLOGIES

1.1. Objectives

The general objective of this report is to identify characteristics of appropriate and successful methodologies for the investigation of safety event at nuclear power plants. In addition, the purpose is to develop a theoretical framework, which can be used when creating criteria for evaluation of event investigation methodologies. As an extension, this framework will also provide guidance for corrective actions to improve safety of a nuclear power plant and on how to implement the actions.

Specifically, the goals of this section are:

(1) To apply current knowledge of operating experience for the development of a framework that can be used for selecting amongst the various event analysis methodologies.
(2) To identify characteristics of methodologies that are appropriate for event investigation which can also be used to evaluate event investigation methods.
(3) To provide information that can be used for choosing corrective actions to improve plant safety.

1.2. Basic assumptions

The following basic assumptions should be considered and used as guiding principles to meet the objectives:

(a) The goal of safety event investigation and analysis is to ensure that lessons are learnt from events and these are fed back into the organization to ensure improvement of the safety of the NPP.
(b) The general framework covers the dynamic interaction of diverse subsystems in occurrences of events and recognizes that most events have multiple causes that should be pursued during event investigation and analysis activities.
(c) To get the most out of an event investigation methodology, the investigation has to be carried out in a healthy safety culture environment.
(d) Systems considered important in an event analysis include:
  — people (e.g. operators, technicians, engineers, inspectors);
  — technology (e.g. hardware, software, mechanical components, instrumentation and control components);

- organization (e.g. for quality assurance, maintenance, supervision, training, planning, management, procedures); and
- the environment (e.g. social, physical environment, regulations).

1.3. Event types

Recognizing that it is not practical that every event which occurs should undergo a full in-depth analysis, a hierarchical approach should be developed consisting of event types, these event types are described below:

(1) Events of high importance are investigated and analysed and usually are required to be reported to regulators.
(2) Events that meet the reporting criteria set by the regulatory body are subject to in depth investigation and analysis.
(3) Those events that are of less apparent significance or importance, but may nonetheless warrant investigation and more detailed analysis based on the learning potential for the plant staff, typically non-reportable events.
(4) Events which include actions where safety did not receive the overriding priority warranted by the safety significance of the event. For these events, investigation and analysis are considered by the plant staff based on the need for correction of immediate apparent causes of the event and on the perceived value of learning from the event. The investigation and analysis of these types of events may vary in depth and scope, based on the complexity of the event.

Examples of such types of events are included in Section 3.2 of this report.

1.4. Investigation and analysis of single events

As used in this report, single event investigation and analysis refer to those activities performed immediately following the occurrence of an event. These events are typically the ones identified or occurring during the day-to-day operation of nuclear power plants. Important characteristics that an event investigation and analysis methodology suitable for application to these events include the following:

- The scope of the event investigation and analysis methodology covers all the systems already described above, i.e. people, technology, organization and environment.
- The methodologies are flexible to meet the needs of plants with varying levels of event investigation and analysis expertise.
- The methodologies are efficient, economical, and practical.
- The methodologies encourage the use of teams in the investigation and analysis of events.
- The users of the methodologies have adequate training in the methodologies they apply.
- The methodologies counteract human problem solving and decision biases such as: monocausal thinking, early hypothesis formulation and orientation, search for scapegoats, and hindsight bias.
- The methodologies promote proactive actions in order to detect problems before they occur.
- The methodologies are easy to review, making it possible to follow each step in the process up to the conclusions and results.

— Collection of event information and review of significant data.
— Analysis in search of contributing factors.
— Development of focused and practicable corrective actions.
— Determination of the efficacy of the corrective actions.
— Prioritization among corrective actions.
— Assessment and follow-up of corrective actions.
— Event reporting that emphasizes and facilitates learning (including support for event aggregation) in the process of operating experience feedback.

1.5. Investigation and analysis of event aggregates

As used in this report, event aggregates refer to groups of prior events with common aspects or themes that may warrant investigation. The principles for forming these groups include: organizational units, plant states, time periods, work procedures, documents, etc. The groups may be identified through database analysis or through review by station staff, regulators, industry peers, human factors or other experts. Data analysis activities include event trend analyses, self-assessments of a series of events performed by plant management, and independent reviews of past events by regulatory and industry peer groups or other experts.

An event analysis methodology suitable for review of event aggregates should have the following characteristics:

— Event trending and analysis should be based on clearly defined data sets (valid high quality data are necessary).
— Methodologies used should consider accessibility and usability of national and international databases for event evaluation purposes.
— The users of the methodologies should have adequate training in statistical methods.

1.6. Operating experience

There is a direct and very important relationship between event investigation methodologies and the performance of operating experience at all levels. A good event investigation methodology, used by trained people, will result in high quality information to be shared by target groups.

The basic characteristics of an effective operational feedback process consist of:

— an information selection process;
— coding the information;
— processing the information;
— decision making;
— implementation of results;
— assessment of outcomes;
— feedback to the different target groups.

An examination of the effectiveness of operating experience feedback from events subject to formal investigation is discussed in Section 3.

1.7. Safety culture

The concept of safety culture as defined in INSAG-4 [1] is:

"*Safety culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance.*"

This concept has a direct relationship with the basic assumptions developed in Section 3.2. because it involves shared goals and systems. All organizations in the nuclear industry have a common concern for the maintenance and improvement of safety. However, the approaches are different in the understanding of the concept and the actions taken in relation to it.

Safety culture is recognized as a subset of the wider organizational culture. Many practices that improve organizational effectiveness can also contribute to enhance safety. An effective event investigation methodology is a specific practice which contributes to a healthy safety culture.

The relationship between safety culture and an event investigation methodology is clearly addressed in Section 5.4 of IAEA Safety Report Series No. 11 [2] as a specific practice to develop safety culture.

2. REVIEW OF THE METHODOLOGIES

2.1. Introduction

At a Technical Committee meeting organized by the IAEA on 22–26 November 1993, a number of root cause analysis methodologies which were in use or under development were presented and an assessment of their individual strengths and limitations was carried out.

Following several years of continued application of these methodologies, this co-ordinated research project reviewed the 1993 report in the light of their experience and current perceptions. Where sufficient knowledge of individual methodologies existed, the existing strengths and limitations of these methodologies were reviewed to provide an updated assessment.

This co-ordinated research project further investigated some of these methodologies by analysing individual events using different methods to determine the strengths and limitations of the various methodologies.

After studying the methodologies and performing further research on various methodologies over the three year period of the CRP, the participants focused on the following established methodologies:

— ASSET (Assessment of Safety Significant Event Team);
— HPES (Human Performance Enhancement System) and closely related methodologies;
— MORT (Management Oversight and Risk Tree).

Several additional methodologies and methods were developed in different countries during the course of the CRP research, such as SOL-VE (in Germany), PRCAP and CERCA (in Hungary), AEB (in Sweden) and PSA based investigations (in Finland). The status of these methods at the time of drafting is as follows:

— SOL-VE is a computer based event analysis methodology including the administration of events and associated corrective actions within a data base. It covers the identification of human factors as well as technical factors and supports the whole procedure of event analysis as a problem solving process. The methodology has been developed in Germany and piloted at several NPPs, and currently is being used by one NPP on an ongoing basis. The tests and experiences show that it fulfils the necessary criteria and that it is a useful and easy to handle methodology. The application includes data base functions that allow trending of various root causes across all event investigation results.

— PSA based event analysis methodology — A procedure for risk informed analysis of events at NPPs developed by STUK (Finland). The method is used to determine the safety significance of events and identify precursors. In PSA terms, precursors are infrequent initiating events and/or equipment failures that, when coupled with one or more postulated events, would result in a plant condition leading to a core damage. The calculated probability of core damage given the failed equipment associated with the particular event is termed a conditional core damage probability and can be used as a measure of the safety significance of that event.The method is used mostly to evaluate events with failures in safety related systems or systems covered by Technical Specifications. Plant specific living PSA models are applied to the risk calculations of events. Conservative assumptions and model simplifications are often used in order to reduce the analysis burden. The probability of core damage is calculated based on the increased risk level due to the failure and the duration of the failure.

— Accident evolution and barrier function (AEB) — This method was developed by Sweden. In the AEB method, an accident evolution is modelled as a sequence of malfunctions and errors in human and technical systems leading to the accident. Coupled with most links in this sequence there are possibilities to arrest the evolution through *barrier functions*, (e.g. a physical barrier function) controlled by *barrier function systems* (e.g. a computer-controlled lock). The manual of the AEB method [3] includes several steps and issues, such as deciding when to stop going further back in the chain and barrier function analysis. The manual also contains material of interest for analysis using other methodologies for accident event analysis.

— PRCAP — The Paks Root Cause Analysis Procedure developed in Hungary was originally an adaptation of HPES and MORT. Nevertheless, significant modifications and amendments were made to satisfy the specific interests and practices of safe and reliable operations at the Paks NPP. PRCAP represents a disciplined approach to systematic investigations and analysis of root causes of events that occur at operating NPPs. PRCAP includes a number of techniques such as change and barrier analysis, event and causal factor charting, event tree drawings, and causal factor searches.

— CERCA — Developed in Hungary, CERCA is a computer based event investigation documentation method in use at the Paks NPP. Implementation is currently incomplete due to fiscal constraints.

Having reviewed these methodologies, the group made the following general observations.

— ASSET remains as an established methodology in use in several countries.
— HPES is widely used throughout the nuclear industry and in several countries that have adopted this methodology during the three-year period of the CRP.
— MORT was not widely used by the participants in the CRP but was felt to be a viable methodology by several of them. Note that MORT is a commercial product and can only be used under license.
— Of the remaining methodologies, Fault Tree Analysis is considered by CRP participants to be integral to many other root cause analysis methodologies and can be considered as a simplified version of MORT

2.2. Review of strengths and limitations

The CRP focused primarily on the ASSET, HPES and MORT methodologies. The assessment of the ASSET methodology provided in this report relies on the IAEA ASSET guidelines issued in 1991 [4]. The assessment of the HPES methodology relies on INPO Good Practice 90-004 [5]. The strengths and limitations of these methodologies are summarized below.

Concerning ASSET and HPES (and associated methods), the CRP participants made the following observations:

— They are freely available to NPPs and regulatory organizations through the IAEA, WANO, and INPO.
— They are widely used with a good level of understanding in many countries.
— They are well documented.
— They are well structured processes which provide guidance and consistency for event analysis.
— Both methodologies require a commitment of resources to complete the investigations.

For MORT, the CRP participants observed that:

— MORT is used by one participant country to the CRP as the preferred method for Augmented Inspection Teams (AITs)
— MORT uses graphic checklists which were found by that country to facilitate the investigation process.
— the MORT methodology and associated training can only be used under license.

Note that all three methods require training and involve skills that require routine practice to maintain full proficiency.

The additional strengths and limitations of these three methodologies studied by the participants to the CRP are discussed below.

2.2.1. ASSET

Strengths

- Useful for investigation of generic events which are applicable to a large number of NPPs.
- Can be useful for investigating a single event of high safety significance which has related managerial and organizational aspects.
- Useful for retrospective review of a population of events where a trend of recurring problems has been identified.

Limitations

- Uses a different terminology and definition of root cause compared with other techniques.
- Because the method identifies deficiencies in management, organization and higher policy issues, knowledgeable senior staff with practical experience are needed to perform the analysis.
- Issues and corrective actions identified by ASSET methodology are often at high level, more pertinent to management policy and philosophy, and of a generalized nature. This makes development of concise, measurable, and achievable corrective actions difficult.
- ASSET services are no longer supported by the IAEA and hence, training and further improvements for the ASSET methodology may no longer be available through IAEA.

2.2.2. HPES

The HPES methodology incorporates many tools such as task analysis, change analysis, barrier analysis, cause and effect analysis, and event and causal factor charting. Additionally, many similar methodologies have been developed from HPES and adapted where necessary to suit the specific requirements of individual organizations (for example HPIP by the USNRC, MTO by the Swedish NPP operators , KHPES by the Korean NPP operators, JHPES by the Japanese NPP operators, and HPES by the United Kingdom NPP operators).

Therefore, for the purposes of a strengths and limitations review, these methodologies can be considered to generally fall into one ‘school’ of approach.

Strengths

- While the main focus is on human factors, it has been demonstrated that it can be equally applied to equipment and design related issues.
- Systematic approach which can be used by non-human factors specialists to give consistent results following a limited period of training and practice in the methodology.
- The event and causal factors charting is a powerful method for presenting the event genesis, root cause development, and failed barriers in a concise and easily understood format.
- Corrective actions which address the root causes can be easily developed from the event and causal factors chart.

- Involvement of NPP line management in corrective action identification has proven effective in improving ‘ownership’ by line managers for corrective actions in their area.
- Effective tool for the investigation of individual events, with a proven track record at many NPPs.
- Can be used flexibly or in a shortened format if required. This is particularly useful for ‘apparent cause’ analysis of near miss or low level events for subsequent use in significant event precursor trending.
- Has been proven effective in identifying training and knowledge weaknesses whenever they are contributing factors to events.
- Can be used proactively to identify and correct ‘error-likely’ conditions and situations before they result in events.
- Identification of specific root causes and causal factors by coding allows for easy trending of event contributing factors.

Limitations

- Organizational and managerial factors are not strongly supported by the methodology. It can be difficult from a single event investigation to target management weaknesses.
- The application of the whole process can be time consuming, particularly in the area of interviews of personnel. Such interviews can be difficult, especially if there is no ‘blame tolerant’ culture in place. However, it has been shown that continued use of HPES in some plants has promoted development of a healthy blame-tolerant environment.
- To maintain effectiveness, trained investigators need to practise investigation skills routinely.

2.2.3. MORT

MORT is a methodology originally developed by the United States Department of Energy for analysing events of nuclear safety significance, and was later adapted for more general accident investigation and safety assessment.

Strengths

- MORT was found to be adaptable for quick analysis of simple events.

Limitations

- Perceived by some to be complex and costly.
- As with other event investigation methods, MORT requires training and experience for proficient use.
- MORT is a commercial product that is only available for a fee.

2.3. General observations

The ASSET service previously available from the IAEA is being replaced with a new service called PROSPER (peer review of operational safety performance experience). The ASSET methodology will continue to exist and be used in several countries. However, training and future improvements to ASSET may not be undertaken by the IAEA. The PROSPER service has been developed and will be available from the IAEA in place of

ASSET. This new service involves self-assessment and peer review of the use of operating experience, but it is not an event investigation methodology.

The CRP participants have found that, though the ASSET methodology will no longer be actively supported by the IAEA, this methodology may continue to be appropriate for use as an event investigation tool by NPPs already familiar with it. In this context, it may continue to be used for the investigation of discrete events. However, in the experience of the CRP participants, the ASSET methodology, when applied to discrete events of limited safety significance, develops root causes which are at the higher managerial levels, and as a result generate more global corrective actions. Such actions have been found to be difficult to implement due to issues relating to high cost and insufficient focus of ownership and accountability. Additionally, in such cases, the potential exists to reduce the impact and opportunity for learning from experience if such global actions are transferred to other utilities in the international event reporting forum. The working group participants experience indicates that the application of other available methods in this respect can be more effective than the ASSET methodology for discrete events.

The HPES and associated techniques have now been adopted by many countries and organizations. The approach has been proven to be practicable and successful across a broad spectrum of NPP operators and cultures, having been adapted where necessary to meet local needs. Its limitations in the managerial and organizational areas have been addressed by those organizations who are increasing focus on these issues (MTO, U.S.A. utilities, KHPES, JHPES, HPES in the United Kingdom, to name a few).

MORT was not found to be widely used by the CRP participants, but one participating country that researched MORT found it to be suitable for investigations of discrete events, and has adopted it as the working methodology for their regulatory Augmented Inspection Teams.

The work performed by the CRP participants also indicates the value of performing near miss or low level reporting and trending precursors to proactively identify error likely situations and weak defences before they contribute to consequential events

Additionally, the work done by the CRP participants has highlighted the importance of training, resources and management commitment and support for the success of any event investigation and learning process.

2.4. Recommended approach

The opportunity exists to maximize effectiveness of learning from experience at NPPs by promoting the best event investigation practices available from a series of methodologies in the form of a ‘toolbox’ approach.

Recognizing that different techniques apply in different situations, an attempt is made below to categorize the incidents/situations in the following matrix:

SITUATION	SAFETY SIGNIFICANCE	EVENT POPULATION
1	Low	Single
2	High	Single
3	Low	Group or recurring
4	High	Group or recurring

Using this table it is possible to attribute suitable event investigation techniques to particular situations. For example, for those NPPs already trained in ASSET methodology, ASSET may be the most appropriate tool for Situation 4. For Situations 2 and 3, a combination of the ASSET, HPES, or MORT methods might be the most appropriate, whereas for Situation 1, the HPES methodology, perhaps in some instances in the truncated ‘apparent cause’ format, or MORT, would be the most appropriate.

The possibility of developing (where possible) some degree of integration of ASSET with HPES, and/or MORT to form an integrated event investigation method ‘toolbox’ should be considered.

3. EXAMINATION OF THE EFFECTIVENESS OF OPERATING EXPERIENCE FEEDBACK FROM EVENTS SUBJECT TO THOROUGH INVESTIGATION

3.1. Introduction

The purpose of this section is to outline the principles of an effectiveness review following application of event investigation, taking account of information contained in utility, regulatory body and international databases.

Effective feedback of operating experience is essential to meet the aim of:

— increasing the safety, reliability and availability of NPPs.

This aim can be met by:

— decreasing the number of events, particularly safety significant events, and
— avoiding recurring events.

Assumptions for effective operating experience feedback (OEF) include:

(a) A primary responsibility of management is to develop a culture in which lessons learned from events is considered beneficial and a vital component for optimum performance in operating experience.

(b) Managers and team leaders remain cognizant of station efforts to learn from events and consider the following to be important aspects:

— timeliness of event review and evaluation
— identification and analysis of adverse trends
— timeliness and effectiveness of actions taken to address lessons learned.

(c) Line managers need to take a personal interest in communicating important station and industry operating experience information and to personally ensure that the information is being used effectively.

(d) Procedures or instructions should be developed to define how the station will use the results of event investigation.

A simplified model illustrated in Fig. 1. shows the parts of the OEF process relevant to this examination.

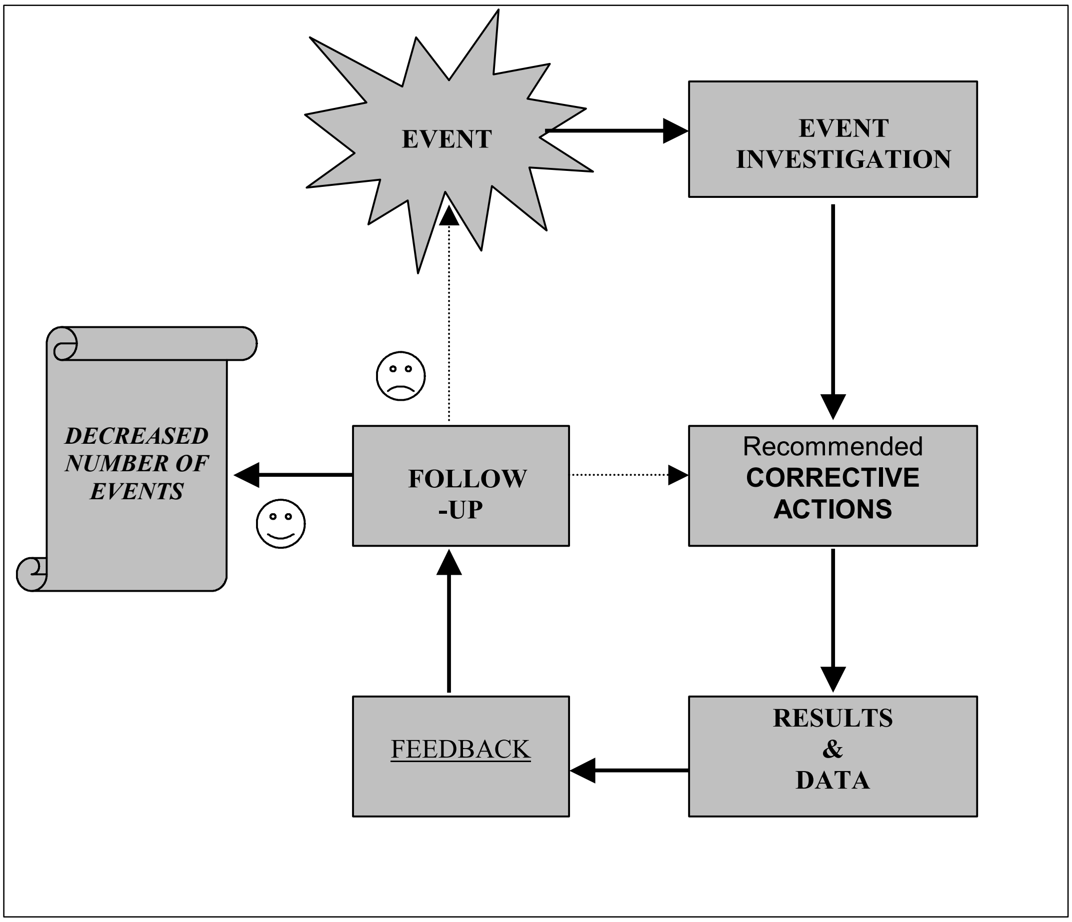

FIG. 1. Simplified model of the operating experience feedback process.

Key to Figure 1

MAIN ACTIVITY (from the model)	ACTIONS
EVENT INVESTIGATION	Select appropriate investigation method
PRODUCE RECOMMENDED CORRECTIVE ACTIONS	Prepare 'SMART' corrective actions based upon causes and weak or missing barriers/defences
PROCESS RESULTS & DATA	Select, approve and prioritize corrective actions Prepare action plan Select and code event information Trend data
FEEDBACK	Implement action plan Share OE/lessons learned internally Share OE externally (report to IRS and/or WANO)
FOLLOW-UP	1. of corrective actions 2. to target work groups 3. to include an effectiveness review

3.2. Events subject to investigation

It is important to specify those events that should be subject to thorough event investigation. These may include non-consequential events or near misses where these recur or where they are likely to contain useful generic issues or learning points for others.

Note that for equipment related events, the results and data coming from event investigation will be more useful for countries operating reactors of similar design, or equipment with similar characteristics, or for equipment operating in similar environments. For events with human performance causal factors, the lessons learned may be useful to increase human or organizational reliability in plants, regardless of the type of reactors they operate.

Events suitable for thorough event investigation include, inter alia:

— safety related events such as:

- severe or unusual transients (general and non-general events)
- malfunction or improper operation of safety systems
- major damage to safety equipment
- unexpected or uncontrolled release of radioactive material
- fuel handling or storage events with safety implications
- events not considered in the design basis

— recurrent and frequent similar deviations or minor events
— some near misses
— major injury to personnel
— unplanned exposure to personnel above prescribed limits
— events causing significant unavailability of plant.

3.3. Attributes of effective corrective actions

An effective corrective action should meet the following criteria;

— It should prevent recurrence of the undesirable condition by addressing the causes and flawed defences.
— It lies within the capability of the utility to implement it within agreed and specified time-scales
— It allows the utility to meet its primary objective — the safe and reliable production of power — with negligible impact on the environment.
— It will not have any detrimental effect on other plant systems nor affect human performance.
— The corrective action itself and responsibility for implementing it is clearly stated, unambiguous and recognized by the acting party.

Whenever plant personnel undertake event investigations, to promote 'ownership' of corrective actions, it may be prudent to have them reviewed or written by plant staff who are likely to implement these actions. Employees who identify problems or those involved in developing corrective actions should receive prompt feedback about the progress of implementation of the corrective actions.

A database (or action tracking system) is essential to monitor the status and effectiveness of corrective actions. To avoid duplication of effort and aid prioritization, corrective actions arising from all processes (evaluations, audits, defect reports, for instance), should be stored in the same database. In this way corrective actions may be appropriately prioritized and tracked to completion.

In deriving corrective actions it may be necessary to consider changes in design, procedures, training or organization. It is not possible to prescribe this more exactly since national culture may be determinant: to resolve an identical problem at two similar plants in different countries, one plant may opt to make changes to procedures (strengthening administrative barriers), whilst the other may decide to modify equipment (strengthening physical barriers).

When developing corrective actions, safety and environmental considerations must be of paramount importance; other factors to be taken into account include; safety policy and plant operating regime. Pragmatically however, corrective actions may have to be a compromise between the 'perfect' technical solution and the most cost effective solution.

Beyond being approved, recommended corrective actions must be prioritized according to:

— safety significance
— recurrence of the event
— injury to personnel
— harmful effects to the environment
— damage to the plant.

Another factor that influences the effective implementation of corrective actions arising from event investigation is the top level commitment in an organization to the OEF process, particularly to those actions arising from the regular screening of both internal and external event reports. A process of accountability helps to ensure that actions arising from shared operating experience are implemented in a timely manner.

3.4. Use of data

Because the operating experience effort may be widely dispersed, applicable information needs to be promptly distributed and widely available to those who will make best use of it.

It is important to be able to access, search and retrieve event information from databases. This enables trends and patterns to be determined and may even provide the opportunity to be proactive in dealing with 'error likely situations' identified from event investigation. If error likely situations — that may be event precursors — can be identified, they can be managed and eliminated before evolving into a safety significant event.

The following information will be useful in optimising the output from event investigation:

— event category
— affected plant system
— work groups most likely to learn lessons from the event
— activity
— plant status
— causes
— consequences
— corrective actions.

For effective learning from both event investigation experience and from good practices identified by evaluation/assessment processes, it is to advantage to:

— specify how information in databases should be used, (e.g. 'prevent events' in WANO significant operating experience reports can be used as self-assessment questions);
— determine how useful utilities and regulators find information in databases;
— establish which types of information need to be more highly developed to improve the usefulness of the systems.

There is a need to examine the source/origin of information in databases and how it is used. This should be accomplished by scrutinizing arrangements at utilities and/or countries with ‘good’ performance and, where possible, emulating those features which led to the good performance.

It is desirable to share operating experience with other countries, particularly information arising from aggregated or generic event analysis. The responsibility for co-ordinating this must lie with an appropriate international organization such as:

IAEA/OECD-NEA, through the AIRS database (set up for regulators and licensees)

or

WANO, through the operating experience (OE) information issued for its members.

If possible, data should be collected to ensure that the corrective action *actually implemented* meets the intent of the approved recommended corrective action as originally proposed. This can be done during a final review of the event.

An overall review of all aspects of the station’s use of operating experience should be conducted periodically. The frequency of this effectiveness review will be based on self-assessment of station programmes and also on international peer reviews such as IAEA PROSPER missions or WANO peer reviews.

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GLOSSARY

Note: These terms and their explanations were compiled solely for the purposes of the present report on the IAEA co-ordinated research project on methodologies for the analysis of nuclear power plant incidents. The list does not represent a consensus or an endorsement by the IAEA. Numbers in parentheses refer to the source documents listed at the end of the compilation.

action tracking system. A method used to monitor progress of completion of corrective actions identified during the event investigation process.

barrier. Anything that is used to protect a system or person from a hazard and includes physical barriers, natural barriers, administrative controls and human actions (2).

Also, administrative or physical controls designed to promote consistent performance that should inhibit an inappropriate action (9).

Barriers can be either administrative or physical in nature.

barrier analysis. An investigation technique used to determine what could have prevented the event or significantly mitigated its consequences (2).

Also, a tool that evaluates the effectiveness of barriers to prevent inappropriate actions by people. Barriers can be administrative or physical (8).

Also, a formal method of identifying the individual occurrences that, if avoided, would have prevented the event from occurring or would have significantly mitigated its consequences. A barrier to an event can be any physical boundary, natural occurrence, human action, and/or administrative control that prevents an event from occurring (7).

barrier function. Those functions that contain, prevent, prescribe, monitor, and so forth.

barrier system. A system that establishes barrier function systems such as material (physical barriers), functions (locks, passwords), symbolic (signs, postings, and procedures), and immaterial (self checking).

blame tolerant. Organizational ability to accept slips and lapses by workers without sanctions. In such a framework, individuals feel free to report near misses and events without fear of reprisals or recriminations.

causal factor. A factor that influences the outcome of a situation. The reasons for an action that was taken or an event that occurred in the sequence of events that led to the grounds for an investigation (2).

Also, a condition that shapes the outcome of a situation (3, 6, 9).

Also, causes that, if corrected, would not of themselves have prevented the event, but are important enough to be recognized as needing corrective action to improve the quality of the process or product (12).

change analysis. An investigation technique that compares two situations to determine the differences and the effect those differences have on the outcome of each situation. Used to identify any variation in a system, process, procedure, or methodology that caused undesirable outcomes which contributed to the event (2).

Also, a root cause technique that evaluates if change had any effect on the event. Change analysis seeks to determine what is different about an event situation from other times the task was performed successfully (8).

consequential event. An event that results in adverse consequences (9).

contributing causes. Factors that, if corrected, would not by themselves have prevented the event, but did add to the condition by facilitating its occurrence or increasing its severity and are important enough to warrant correction to improve the quality of the process or product.

Also, causes that, if corrected, would not by themselves have prevented the event, but are important enough to be recognized as needing corrective action to improve the quality of the process or product (6).

contributing factor. A condition that may have affected the event (6, 9).

corrective action. Measures taken to alleviate the symptoms of a problem or to eliminate or diminish the causes of problems. Also, action taken to prevent recurrence of an identified adverse condition or trend (9).

early hypothesis formulation. The tendency of individuals to remain with an early hypothesis concerning a phenomenon and not testing other equally likely explanations that later appear.

error likely situation. A task related predicament involving a potential error being provoked by unfavourable jobsite conditions (error precursors) that reduce the likelihood for success (1).

error precursor. Unfavourable prior conditions that reduce the opportunity for success at the jobsite (1).

event. An action or happening that occurred during some activity (1).

Also, an unwanted, undesirable consequence for the safe operation of a plant (generally in terms of reduced safety margin) (1).

Also, any unintended (unusual) occurrence or sequence of related occurrences, including human error, equipment failures, or other mishaps, the consequences or potential consequences of which are not negligible from the point of view of nuclear safety (12).

Also, an undesirable consequence that challenges the safety of the reactor core (4).

Also, an undesirable occurrence (6, 9).

Also in the context of the reporting and analysis of events, an event is any unintended occurrence, including operating error, equipment failure or other mishap, the consequences or potential consequences of which are not negligible from the point of view of radiological protection or nuclear safety (13).

event aggregates. Groups of events with common aspects or themes that may warrant investigation.

event analysis. The process of review of all aspects of an event to determine root cause, causal factors, and lessons learned.

event and causal factor charting. An investigation technique used to organize information about an event into a sequence of actions which led to the event and the potential reasons for those actions (2).

Also, a graphical representation of the event charted on a time line to show cause and effect relationships and illustrate how human behaviour has affected performance (8).

fault tree analysis. A root cause analysis technique utilizing a logic tree to display all the possible causes of an event or occurrence.

hindsight bias. The tendency to believe that a person was more correct in his or her judgement before or during the course of an event than he or she actually was at the time.

human factor (as applied to systems). The area concerned with the application of knowledge about human capabilities and limitations with respect to the design of systems and environments and the selection, training, and management of staff to achieve optimum interaction between staff and systems in terms of system efficiency and safety (7).

Also, any attributes to characterize human activities for functioning technological systems (12).

Human Performance Enhancement System (HPES). A method sponsored by INPO that utilizes a family of techniques to investigate events, with particular emphasis on determining human performance aspects (3).

Human Performance Investigation Process (HPIP). A method used by the United States Nuclear Regulatory Commission for investigations of events that involve human performance issues at nuclear facilities (2).

line manager/management. Includes all managers in the chain of command from the first-line supervisors to the top manager (5).

monocausal thinking. The tendency to concentrate on one cause in explaining events with many interactive causes.

near miss. An inappropriate action without actual adverse consequences.

A potentially significant event that could have occurred as the consequence of a sequence of actual occurrences but did not occur owing to the plant conditions prevailing at the time (13).

operating experience. The operational history of NPPs examined for the purposes of improving the safety, reliability, and availability of plants by identifying causes and transferable lessons following events and singling out good practices which may be emulated by other plants or operators.

A process through which knowledge and experience are collected with the purpose of applying lessons to improve ongoing activities.

organizational culture. A set of characteristics and attitudes in an organization that influence the behaviour of those individuals within the organization.

ownership. A sense of responsibility for completion of assigned tasks.

precursor. An event that has the potential for a reactor core damage accident (12).

proactive measure. Taking action to prevent an event or an error by identifying the organizational contributions to problems before they occur (1).

quality assurance. All those planned and systematic actions (controls) necessary to provide adequate confidence that a structure, system, or component will perform satisfactorily in service (5, 12).

Planned and systematic actions necessary to provide adequate confidence that an item, process or service will satisfy given requirements for quality, for example, those specified in the licence (13).

recurring event. An event that has happened before or which, following evaluation, is determined to have root causes similar to those identified as having contributed to previous events (6).

remedial action. Step taken to mitigate the symptoms or effects of a problem; it might not be the only step needed to prevent recurrence.

root cause. The fundamental cause(s) of an event that if corrected, will prevent recurrence of the event or adverse condition (9, 12).

Also, the most basic reason(s) for an event that can be reasonably identified and that over which management has control to remedy (2).

The fundamental cause of an initiating event which, if corrected, will prevent its recurrence, namely, the failure to detect and correct the relevant latent weakness(es) and the reasons for that failure (13).

root cause analysis. Any method(s) used to identify the root cause of performance problems or adverse trends (6).

safety assessment. Assessment of all aspects of the siting, design and operation of an authorized facility that are relevant to protection and safety. This will normally include risk assessment (13).

Analysis to predict the performance of an overall system and its impact, where the performance measure is radiological impact or some other global measure of impact on nuclear safety.

safety culture. That assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance (10).

screening. Reviewing operating experience information to determine what information is valuable for and applicable to a particular plant.

self-assessment. A systematic evaluation of an organization's performance, with the objectives of finding opportunities for improvement and exceptional practices. Normally performed by the people involved in the activity, but may also be performed by others within the organization with an arm's-length relationship to the work processes.

Also, a continuous process of comparing performance with desired objectives to identify opportunities for improvement.

A routine and continuing process conducted by management at all levels to evaluate the effectiveness of performance in all areas of their responsibility. Self-assessment activities include review, surveillance and discrete checks, which are focused on preventing, or identifying and correcting, management problems that hinder the achievement of the organization's objectives, particularly safety objectives (13).

task analysis. An analytical process for determining the human behaviors such as sensing, interpreting, remembering, deciding, initiating, adjusting, terminating, and so forth, that must occur within specific accuracy and time limits. The resulting data may be used to modify function allocation, to establish design criteria, and to establish selection and training requirements (7).

Also, a technique used to determine exactly what the individual should have been doing compared to what was actually done (8).

time series. A statistical concept for measures grouped over time and analysed with time as an independent variable.

transient. An unanticipated change in a plant parameter.

trend analysis. A statistical methodology used to detect net changes or trends in levels over time.

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