Achieving excellence in human performance in the nuclear industry through leadership, education and training

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Abstract. This article describes IAEA, and particularly its Nuclear Power Engineering Section, activities carried out to assist in improving human performance and personnel training in the nuclear industry. The article also describes cooperation between the IAEA and other international agencies and national institutions in the field of personnel training that have led to sustainable improvements in the NPP personnel performance and, finally, enhancement of NPP safety and efficiency. Current trends in the areas of human performance improvement and personnel training development are also discussed.

1. Introduction

As the nuclear power industry continues to be challenged to maintain high safety standards, while responding to the pressures of more competitive energy markets, it becomes more important than ever to maintain excellence in human performance and ensure that NPP personnel training provides a value to the organization.

Based upon experience, both within and outside the nuclear industry, the following are factors that have been found to be effective mechanisms to improve human performance:

— Management sponsorship and leadership driven improvement initiatives;
— Business planning processes that integrates a human performance improvement strategy;
— Communication at all levels that facilitates excellence in human performance;
— Training and personal development based upon a systematic approach to training (SAT);
— Established standards and expectations for human performance;
— Immediate positive reinforcement to personnel exhibiting correct behaviors;
— Effective job briefings using both local and industry operating experience;
— Observation programmes focused on the removal of barriers to excellent performance;

In order to achieve and maintain high levels of safety and productivity, nuclear power plants need to be staffed with an adequate number of highly qualified and experienced personnel who are duly aware of the technical and administrative requirements for safety and are motivated to adopt a positive attitude to safety, as an element of safety culture. To establish and maintain a high level of human performance, appropriate education and training programmes should be in place and kept under constant review to ensure their relevance.

There has been considerable focus on the technical competencies related to a nuclear power plant and its processes that are needed by NPP personnel, particularly plant operations staff. However, to ensure that NPPs achieve the high standards with respect to safety, operational performance and economic competitiveness needed in today's environment, it has been recognized that there are other competency areas that are also important, including:

- Open communication;
- Teamwork;
- Leadership;
- Problem resolution;
- Safety conscious focus;
- Business focus;
- Professionalism.

The recent years have brought some significant changes in the world energy market, in which nuclear power plants are operating. Some NPP operating organizations are now privatized; and electricity markets are liberalized and become more and more international. Due to increasing competition, power production costs are now monitored more closely. The opening of electricity markets has led some nuclear power plants to be under the serious economic pressure with a demand for continuous cost reduction. All these factors necessitate NPPs to make their training more cost-effective.

This paper provides information on the trends and examples of nuclear industry initiatives related to human performance and training improvements, with particular emphasis on IAEA-related activities in this area.

2. Systematic Approach to Human Performance Improvement

In the past, much of the focus of formal NPP training and development programmes was on the technical skills of NPP personnel, particularly those of control room operators. The environment in which NPPs operate is continually changing; placing new demands on all NPP personnel, not just operators, to work more efficiently and effectively while continuing to maintain the high levels of safety required of NPPs. In this environment, while technical skills related to nuclear technology remain a cornerstone of successful human performance, it has become increasingly clear that there needed to be a greater focus on maintaining and improving 'soft skills' such as communication, teamwork, leadership, performance assessment, coaching/mentoring, and delegation of authority. The use of SAT has been found to be an effective method for developing training systems that address all competencies needed for effective performance (i.e. integration of both technical competencies and 'soft skills').

Further it has been increasingly recognized that skills and knowledge alone do not ensure excellence in human performance.

One approach that has been suggested is that:

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\text{Performance} = \text{Knowledge} + \text{Skill} + \text{Attitudes} + \text{Opportunity} + \text{Effort} + \text{Motivation}
\]
Training clearly focuses on knowledge and skill, and partially builds or reinforces attitudes. In our industry, the remaining three factors have been addressed separately or sometimes not addressed at all.

As we focus on human performance, we begin to address all the factors of the equation during the "analysis", "design", "development", "implementation", and "evaluation" phases of SAT. This approach provides a more cohesive, integrated approach to achieve the levels of human performance that we need to achieve in the future. Thus, it is suggested that effective human performance in the nuclear power industry should include integration of all of the following:

- **Performance Goals**: setting and rewarding clear, measurable performance goals that emphasize product over process.
- **Performance Analysis**: identifying the causes of human error or detractors from outstanding human performance using systematic research and analysis approaches.
- **Root Cause Analysis**: applying investigative methods to unravel complex situations to determine root causes of performance problems, identify associated causal factors, check for generic implications of an event, determine if an event is recurrent, and to recommend corrective actions.
- **Human Performance Support**: controlling and modifying the work environment, work process, tools, and procedures to support outstanding human performance.
- **Human Resource Management**: applying human resources within complex systems such that people succeed, performance improves, and human error decreases.
- **Organizational Development**: focus on assuring healthy interpersonal and inter-work group relationships and helping work groups initiate and manage change.
- **Employee Development**: learning from experience, mentoring, and feedback that prepare an employee for future challenges.
- **Career Development**: aligning individual employee development with future organizational human resource needs to achieve an optimal match of individual and organizational needs; this includes succession planning.
- **Motivation Incentives**: providing reasons for employees to perform that include financial rewards, opportunities for personal satisfaction, a sense of accomplishment, personal recognition, and visible organizational accomplishment.
- **Performance Feedback**: direct, accurate, constructive comparison between the expected performance and the actual individual or organizational performance.
- **Teambuilding**: organizing workers into teams, granting the teams substantial authority, creating teams that cross functional and organizational boundaries, supporting the growth and development of teams, providing team recognition.
- **Education**: learning focused upon preparation for the future.
- **Training**: learning focused upon the competency needed for employees to perform their current job now and in the foreseeable future.
- **Self-Assessment**: internally motivated and managed evaluation by the people in an organization that is systematic and effective in identifying strengths, weaknesses, business opportunities, and challenges in existing business processes.

Thus, it is suggested that applying SAT in the larger context of human performance improvements leads to addressing all aspects of human performance in an integrated way. It leads to training being more effective because it is utilized as one of an appropriate suite of tools focused on achieving specific human performance improvements. IAEA-TECDOC-1204 *A Systematic Approach to Human Performance Improvement in Nuclear Power Plants: Training solutions* [1], published in 2001, provides suggestions in this regard. The overall process is illustrated in the Figure 1.
3. Integrated Management of Human Resources

In order to ensure that all NPP personnel, are committed to safety, have high professional standards, and are sufficiently competent and motivated, a broad range of activities including proper management of human resources needs to be undertaken.

IAEA TECDOC-1364 Managing human resources in the nuclear power industry: Lessons learned [2], published in 2003, had the objectives to:

— Make middle and senior level NPP operating organization managers aware of the most significant issues in the industry with respect to managing human resources;
— Provide typical symptoms for each of these issues, which may indicate significant performance problems;
— Assist in the solution of performance problems through the identification of practices that NPP operating organizations have found effective in addressing these challenges.

The issues found to be most prevalent in managing human resources for NPP operating organizations are identified in this report. They include the needs to:

(1) Effectively organize work activities and designate responsibilities and authorities;
(2) Effectively train and develop personnel for their assigned responsibilities;
(3) Establish clear performance expectations and assess the extent to which these expectations are achieved;
(4) Provide effective incentives to achieve performance expectations;
(5) Anticipate the long-term human resource and knowledge management needs of the organization;
(6) Establish effective communication methods.

This technical document provides a framework for determining whether such issues are relevant to an organization through identification of typical symptoms and desirable attributes associated with the issue. This document also identifies effective practices to address such performance issues.
4. Managing an Ageing Workforce and Transfer of Nuclear Knowledge to the Next Generation

The safe, reliable, and cost-effective operation of NPPs requires that personnel possess and maintain the requisite knowledge, skills and attitudes to perform their jobs properly. Knowledge includes not only the technical competencies required by the nature of the technology and particular engineering design, but also the "softer" competencies associated with effective management, communication and teamwork. The IAEA Incident Reporting System (IRS) Study on the Loss of Corporate Knowledge based on the 2000-2001 events has indicated that 44 reports from 141 IRS reports reviewed contain the elements related to the loss of corporate knowledge and memory.

Traditional training programmes have addressed explicit knowledge that is contained in written documents, policies, and procedures. However, tacit knowledge that is held in a person’s mind has not typically been either captured or transferred in any formal manner. Rather, new workers have acquired such knowledge over time (if at all) through their working with those who already possess it. As those workers who are in possession of this tacit knowledge leave the workplace for retirement, the effective capture and transfer of that information becomes even more critical. The long-term operation of NPPs requires that this entire body of explicit and tacit knowledge be transferred to new personnel as they enter the workforce. Accordingly, new and different techniques may be required to ensure timely and effective knowledge retention and transfer.

IAEA-TECDOC-1399 The Nuclear Power Industry’s Ageing Workforce and Transfer of Knowledge to the Next Generation [3], published in 2004, provides NPP managers with practical information they can use to improve the transfer of knowledge from the current generation of operating organization personnel to the next generation in an effective manner. A survey on the topic was distributed to NPP operating organizations in IAEA Member States to collect information regarding both the magnitude of the problems in this area and also the methods being used to transfer tacit and explicit knowledge to the next generation of NPP personnel. The information provided in the technical document is based upon the experience of Member States’ operating organizations as well as other related industries.

The main conclusions regarding the strategies for managing an ageing workforce are:

— The nature and magnitude of the ageing workforce problem for the organization should be defined and regularly updated. Staffing plans/work force plans should be prepared that provide a standardized methodology for overall human resources planning driven by strategic and business goals. These plans should identify planned retirements and vacant positions as well as the required staffing levels needed to support business strategies. They should include attrition data, development plans, succession plans and current work force requirements.

— Activities should be strengthened to retain current employees, including regularly soliciting inputs from employees regarding their job satisfaction and motivation, monitoring external markets to ensure that employee benefits and compensation are competitive, and providing opportunities for career/professional development.

— Partnerships with educational institutions and universities that provide qualified professionals for the nuclear industry should be assessed based upon medium and long-term needs, and strengthened where needed. Actions should be taken to make the organization an attractive employer and neighbor in the community.

The main conclusions regarding the capture and preservation of mission critical knowledge and the effective transfer of this knowledge to the next generation of NPP personnel are as follows:

— Experience has shown that one of the principal limitations of such individual transfer of tacit knowledge is the potential for variability in the quality of knowledge transfer. Thus, personal transfer should be supplemented, whenever feasible, by support systems including guidelines,
job aids, individual development plans, structured on-job training and communities of practice that both help to provide consistent and high quality transfer of tacit knowledge as well as to provide a way to transfer tacit knowledge, where appropriate, to explicit knowledge.

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The nuclear industry due to its need for well documented procedures, specifications, design bases, safety analyses, etc., has a greater fraction of its mission critical knowledge as explicit knowledge than in many other industries. This facilitates the task of knowledge transfer. For older plants, in particular, there may be a need for additional efforts to transfer tacit knowledge to explicit knowledge to support major strategic initiatives such as plant licence extensions/renewals, periodic safety reviews, major plant upgrades, and plant specific control room simulator development.

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The challenge in disseminating explicit knowledge is to make employees aware that it is available, provide easy access, in formats and forms that are useable.

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Tacit knowledge is more difficult to identify and disseminate. The challenge is to identify what can be converted to explicit knowledge and to create an environment where tacit knowledge is routinely shared and disseminated (knowledge-sharing culture). No information management system can replace the need for face-to-face interactions, particularly for transfer of tacit knowledge (experts know more than they can say or write).

Many NPPs and operating organizations have taken positive and decisive steps to address the ageing workforce situation. A number of these actions are described in the document, and should be considered for use by others, as appropriate.

5. Preservation of Knowledge, Training and Configuration Management

Another IAEA technical document directly related to the preservation of knowledge is IAEA-TECDOC-1358 Configuration management in nuclear power plants [4] published in 2003. The design bases identify and support why design requirements are established. The inadequate configuration management, along with the compromised professionalism and attitudes towards safety culture, has caused the number of accidents at the nuclear power plants.

The following aspects of configuration management (CM) and training interrelation should be considered and addressed in plant policies and practices:

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Training should be provided on changes to plant procedures and documentation, regulatory developments, modifications of plant systems, structures and components, and changes to the plant organisation structure.

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A mechanism for training programme configuration management should be established. Training materials and tools (e.g. simulators, computer-based training systems) shall be subject to configuration management, and must reflect the actual status of plant processes, equipment and procedures. A systematic approach to training (SAT) provides a solid basis for training configuration management.

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Training programmes for plant managers and relevant personnel should include the modules on CM addressing configuration management vision and concepts, terminology, procedures, practices, and job-specific competencies associated with CM implementation.

Necessary links between CM and training should be established and maintained. The CM system should generate and communicate necessary information to be used in the training development and revision.

6. Integrated Approach to the Development of NPP Managers' Competence

In the past, much of the focus of formal NPP training and development programmes was on the technical skills of NPP personnel, particularly control room operators. NPP managers were generally selected from the population of NPP personnel based on their technical skills and an expectation that
they had some aptitude for management. The environment in which NPPs are operating has continued to change, placing new demands on NPP managers to continue to maintain a high level of safety while at the same time finding new ways to work more efficiently and effectively. It is in that context that more structured ways for the selection, competency development and assessment of NPP managers are required. An integrated approach based on the competencies that these managers need in order to be successful is proposed in IAEA-TECDOC-1024, Selection, Competency Development and Assessment of Nuclear Power Plant Managers [5] published in 1998.

According to fundamental safety principles identified in INSAG-4, Safety Culture [6], the responsibilities of managers are directly connected with the establishment of a safety culture, the role and responsibility of the operating organization, the provision of regulatory control and verification of safety related activities.

In the environment which NPP managers find themselves in today, there is increased emphasis on safe, efficient and effective plant operation. The pace of change in the nuclear power industry has increased, and is likely to remain at a high rate for the foreseeable future. Issues such as competing in open energy markets, increasing economic pressures, and maintaining high safety standards have made new demands on NPP managers at all levels, and will probably make additional ones in the future. Managers are expected to maintain high levels of nuclear safety and at the same time be more efficient to reduce their cost of production. Such circumstances underline the need to give managers the necessary training to succeed in such a demanding environment.

This is part of a manager’s wider role in setting the standards and expectations for all staff in all aspects of company business. In addition, it is essential that managers themselves visibly meet these standards and help staff to understand why they are appropriate.

We should recognize that NPP managers have an extraordinary influence on an organizational culture by:

- Designing and adhering to policy, rules and procedures;
- The way they select employees or remove people from senior positions;
- Being a role-model and organizing specific training;
- The involvement and interest they have in certain activities;
- Their way of reacting in crisis situations.

In addition to written policies, managers’ everyday attitudes and behaviors have an outstanding influence on the establishment of an organization’s culture. NPP managers’ personal sharing of an organization’s values and their demonstration of adherence to the organization’s policies, rules and procedures is the cornerstone by which NPP safety culture, operational culture, and quality culture are established and enhanced.

And it is also important that the organizational culture has a tremendous influence on the managers' competence and behavior.

To improve human and power plant performance, the senior managers in each organization must understand and support the need to develop the management and technical skills of all individuals to perform their assigned tasks. This support should be in the form of modeling the new behaviors and providing resources including adequate funds to develop and implement management and technical skills programmes.

Factors influencing the competencies required by managers are shown in Fig. 2.
Experiences of NPP operating organizations that are leaders in the nuclear industry have shown that a competency based approach to NPP manager selection, development and assessment is a powerful tool in improving the NPP and plant managers’ performance. This approach has been summarized and further elaborated in IAEA-TECDOC-1024. The competencies are defined as groups of characteristics, values, knowledge and skills that lead to superior performance as demonstrated through behavior. It is important that the competencies selected are those that are considered to be critical to the success of both individuals and their organizations.

IAEA-TECDOC-1024 describes a systematic process for identifying the competencies needed by NPP managers. It culminates in a set of suggested core competencies for NPP managers. The following are the general competencies that were developed (details concerning these competencies are provided in reference [5]):

1. ACHIEVING RESULTS. The successful implementation of work activities that leads to the desired outcomes from processes.
2. BUSINESS/COMMERCIAL FOCUS. Demonstrating knowledge of the key business aspects of the organization and the ability to identify ways of optimizing expenditures and creating new opportunities to generate income for the business.
3. CHANGE MANAGEMENT. The ability to manage any kind of change (technical, organizational, social, and cultural) in such a way as to make effective use of resources and achieve high-level results, including maintaining an adequate level of safety.
4. COMMUNICATE. Promoting alignment in the organization through the sharing of ideas, information, policy, and procedures.
5. INFLUENCE. Winning support from others and directing them toward a goal.
6. MAKING DECISIONS. The ability to make decisions based on relevant, factual information taking into consideration the organization and its resources.
7. PEOPLE DEVELOPMENT. The ability to release the full potential of the staff to achieve
performance required by the organization.

(8) PERSONAL CHARACTERISTICS. Effective managers have been found to have some common personal characteristics. The person’s characteristics are instrumental in performing the competencies listed in this report.

(9) PROCESS AND PROJECT MANAGEMENT. The ability to plan, coordinate, and implement the day to day operations and activities that are the responsibility of the line organization or project management position.

(10) SAFETY MANAGEMENT. The ability to develop, maintain and improve an organizations’ ability to identify and control risks to health and safety to meet the expectations of stakeholders and satisfy legal requirements.

(11) STAKEHOLDER FOCUS. Stakeholder focus includes, decision making processes, consideration of the needs of stakeholders, and communication with them during all phases of decision-making. Stakeholders are all individuals or groups that may be affected by an action (e.g., the public, customers, other organizational units, regulators, co-workers).

(12) STRATEGIC THINKING. The ability to understand and influence long-term business strategies and to link one’s behavior and actions to these.

(13) TECHNICAL EXPERTISE. Managers at NPP must understand the application of technology at their facility in sufficient detail to lead their organization, make good business decisions, and apply the results of technical assessments and analyses to the safe, reliable operation of the NPP. Sufficient nuclear technical expertise is necessary to oversee and ensure proper reactivity management, radiological control, residual heat removal, nuclear risk management, conservative decision-making, regulatory compliance, emergency response, and safe routine operation.

Enhanced manager competence leads to improved plant performance by ensuring that other members of the staff are encouraged to contribute to the overall safe operation of the power plant through increased performance, improved morale and job satisfaction.

IAEA-TECDOC-1024 also describes how appropriate management competencies can be used for the selection, development and assessment of NPP managers, including:

— Selection which includes recruitment, promotion and succession management;
— Management development programmes including formal training, job rotation, on-job training, mentoring, and outside assignments;
— Assessment of individual performance.

7. Training Needs Analysis and Evaluation of Training Programmes

Needs analysis and evaluation have a vital role in the entire systematic process of establishing and maintaining training programmes.

The IAEA Nuclear Power Engineering Section – its staff in conjunction with the external experts and the end-users’ teams – is rendering services, mostly through the technical cooperation projects’ mechanism, to perform training needs analysis and evaluation of training programmes of the Member States’ NPP personnel. These services normally include:

— Support in the building of local (end-user’s) Needs Analysis&Evaluation (NA&E) team;
— Transfer of NA&E technology (through providing the objectives and criteria, procedures and job aids, as well as through training, facilitating and coaching the end-user’s NA&E team);
— Assistance in establishing management of NA&E activities and a system for tracking of the NA&E results;
— Conducting seminars for the operating organization and/or NPP managers for reinforcement of their commitments and ownership;

— Support in data collection – through the document review, structured interviews and observations – as well as in data analysis and development of recommendations;

— Assistance in establishing the appropriate Training Review Committees;

— Support in implementation and follow-up of the generated recommendations, both training-related solutions and other necessary management initiatives.

Comprehensive NA&E activities were successfully performed at the NPPs or training organizations in several countries for the entire training systems or particular training programmes, for various job classifications (including operations, maintenance personnel, engineering support personnel, instructor staff, management staff).

8. Improving Training Effectiveness

The determination of training effectiveness is not an easy task because of the many variables associated with personnel performance. For example, for training to make a difference in job performance, line management should be involved prior to training delivery to identify what performance is desired, but not being achieved. Then, training is developed to meet desired performance, which is followed by practice and continued management reinforcement. Because of these other variables, it is very difficult to quantify the contribution of training to performance improvement. The difficulty to isolate training contribution to performance improvement has been documented in a number of research studies. Due to these limitations, a base assumption must be made in order to use any methodology for training effectiveness evaluation. That assumption is that there are some basic principles for developing training and if training programmes are developed and maintained using these principles, then the training provided should be an effective tool to improve the line organization performance. By monitoring various types of training effectiveness indications, weaknesses can be identified and improvements made. These improvements should support an overall improvement in plant performance. Strengths can also be identified to further strengthen the positive aspects of the organization.

IAEA-TECDOC-1358 Means of evaluation and improving the effectiveness of training of nuclear power plant personnel [7], published in 2003, provides information on methods and practices used to evaluate and improve the effectiveness of training. Its main goal is to contribute to improving plant and human performance, meeting objectives of the business (quality, safety, productivity), and improving training programmes.

The main conclusions suggested in this technical document are summarized as follow:

— Training for most NPP personnel is now accomplished using a systematic approach to training (SAT). If carried out properly, the SAT-based process effectively and thoroughly defines the initial and continuing training needed by NPP personnel operating, maintaining, supporting, and managing the plant. As part of the process, training and performance objectives are identified. Once the training is implemented, the achievement of those objectives can be measured by various evaluation methods some of which are described in IAEA-TECDOC 1358[7].

— This technical document also provides an overview of the principles involved in the development, delivery and evaluation of effective training, including the management of training activities. The critical importance of line manager involvement is identified. The need to follow-up on programmes to ensure intended results are achieved is a principle that needs to be accepted by all NPP managers. It is equally important to evaluate the effectiveness of training and modify programmes as needed.

— Training effectiveness evaluation can be conducted at more than one level: the lower and easier to measure levels attempt to evaluate a performance of the training. They evaluate the
effectiveness of the training process by sampling participant reaction, participant learning, and participant behavior change. The higher and most difficult to measure level attempts to determine the impact of training on plant safety, reliability, and cost effectiveness. This is usually limited to anecdotal evidence of positive impacts when training is provided to solve specific performance problems or to prepare for special evolutions. Plant performance indicator trends depend on several variables. The contribution of training to a change in performance is difficult to quantify if other variable factors are also changing. It may be possible for NPP managers to estimate the relative contributions if soft data is tracked over time.

There is evidence that training is often incorrectly identified as the sole remedy for plant performance problems. Problems such as repeat events or repeat component failures typically have multiple root causes. If so, training will not be effective in correcting all deficiencies and training resources may be mis-allocated. Careful analysis of deficient training programmes by INPO (USA) resulted in identification of common problems, which were identified and grouped into seven categories cited as warning flags. When used appropriately, the training warning flags can provide an effective framework for self-assessments regarding the training programmes. The precursors provided for each training warning flag may be used as subjective means in identifying early indicators of developing problems in training programmes. Considering the training warning flags when making changes to training programmes and processes may help maintain the effectiveness of the training provided.

Overall recommendations are as follows:

- NPP management personnel should rigorously conduct training effectiveness evaluations to ensure training and qualification programmes are providing and maintaining the needed competencies.
- NPP management personnel should look for opportunities to assess the impact training is having on overall plant performance and safety to exploit opportunities for training that will “add value” or increase the “return on investment”.
- NPP management personnel should not make resource allocation or budget decisions solely on the results of training effectiveness evaluations because of the difficulty in identifying quantifiable benefits.

Since September 1992, the U.S. Department of Energy (DOE) has been conducting activities related to the improvement of nuclear power plant personnel training at Soviet-designed reactors (SDRs) as part of the International Nuclear Safety Program (INSP) [8, 9]. These training activities were among the first INSP projects started with the intent of improving job performance and safety. A three-pronged approach was taken to (a) introduce a standardized methodology for training, including provision of equipment to support the training function, (b) address culture and management proficiency, and (c) provide full-scope and analytical simulators. The initial focus of the INSP training activities was on the strengthening and additional development of national training centres within both Russia and Ukraine. The work has since expanded to encompass training programme development activities at all Russian and Ukrainian NPPs and training centres as well as at SDRs within other countries. Additionally, simulators and other training centre equipment were provided to support the training function. Where possible, the U.S. has combined efforts with the International Atomic Energy Agency (IAEA) to conduct coordinated training development activities. For example, this has occurred in joint projects conducted in both Armenia and Lithuania.

The effectiveness of U.S. supported training activities at SDRs can be examined from two perspectives. The first issue of interest is whether safety performance has improved because of increased training programme effectiveness. The second issue of interest is the effectiveness of the transfer of the training technology. Results obtained indicate that the training programme activities have been successful on both counts.

A number of measures are useful when assessing the effectiveness of training programme activities. These measures included:
Trainee Ratings of Programme Performance;
Written, Oral, and Performance Test Results;
Increased Training Center and Facility Usage;
Management Support for Training Organizations and Programmes;
Impacts on Job Performance;
Continued Development of SAT-Based Training by SDRs

Training activities have impacted other areas of plant operations:
- U.S. supplied analytical simulators have been used for verification of upgraded software and plant emergency exercise scenarios.
- Development of training documentation has led to changes in operational documentation.
- U.S. supplied full-scope simulators have been used to develop and verify procedures and operating instructions.
- Tests on U.S. supplied full-scope simulators have identified some plant system software program inaccuracies.
- Improved training facilities have provided sites with more effective means to inform the public about nuclear power.
- Training activities have promoted collegial interactions among training and technical specialists at various nuclear power stations.

Although there is still a room for growth and improvement in training programmes and practices, it is clear that the INSP training efforts have fueled and facilitated significant progress towards the goal of improving NPP safety. This progress has been demonstrated in each of the following:
- Improved training facilities and equipment including simulators, computers, etc.
- Qualified training staffs approaching a critical mass of expertise in SAT, simulator instruction, and other significant areas.
- Effective curricula and training materials for fourteen critical job positions.
- Increased management awareness of and support for training.
- Increased job proficiency among the NPP workforces.
- Improved job performance.
- Improvement in NPP safety.

Each of these areas is discussed in more detail in [8] and [9].

Those positive results became possible due to the effective transfer of proven SAT technology, broad experience, capabilities and dedication of national personnel, and multi-aspect international cooperation in which all parties involved as well as the entire nuclear power industry benefit.

9. Recent Developments, Publications and Future Activities

The International Atomic Energy Agency together with its Member States has provided for coordinated information exchange and developed guidance on methods and practices of improving human performance and personnel training. The Nuclear Power Engineering Section (NPES) has the lead role for IAEA activities related to the NPP personnel performance improvement, personnel training and qualification. In this effort, NPES conducts training workshops, sponsors consultants' meetings directed toward specific questions, brings together advisory groups to solicit the views of Member States, develops technical documents, helps to enhance and maintain communications between Member States and individual NPPs, and supports coordinated research programmes. The main output of these activities is guidance on proven practices and methodologies including the
following: systems and processes to maintain high standards of personnel performance; improvement of inspection methodologies; performance indicators for training, self-assessment and external assessment; training standards; managing an ageing workforce; core competencies, nuclear knowledge management and outsourcing without compromising safety.

Almost thirty documents have been published by the IAEA since 1987 in the nuclear power training field. IAEA Safety Standards Series NS-G-2.8 Recruitment, Qualification and Training of Personnel for Nuclear Power Plants, published in 2002, is the result of cooperation between the IAEA various departments and Member States, and has become a real benchmarking document for establishing reliable training programmes. All recent IAEA publications may be downloaded now from the IAEA web site: www.iaea.org.

Examples of other recent developments - not mentioned yet in the previous sections of this paper - that provide guidance and disseminate good practices in the training field are:

- Experience in the use of systematic approach to training (SAT) for nuclear power plant personnel [11];
- Analysis phase of systematic approach to training (SAT) for nuclear power plant personnel [12];
- Assuring the competence of nuclear power plant contractor personnel [13];
- Use of control room simulators for training of NPP personnel [14];
- Development of instructors for NPP personnel training [15];
- Coordinated research project on information management solutions for SAT applications.

The IAEA Guidebook on Nuclear Power Plant Personnel Training and Its Evaluation (IAEA Technical Reports Series No. 380, 1996) has become a real "road map" for many operating organizations, NPPs and training centres in establishing quality training systems and training programmes. This Guidebook provides information on the reasons why a systematic approach to training (SAT) is now international best practice for the training and qualification of NPP personnel as well as for the evaluation of this training, and also provides a detailed description of SAT methodology.

SAT-based training eliminates or minimizes the competency gaps, which affect nuclear power plant safety and efficient operation. An SAT-based training system provides continuously the inputs for other processes to enhance NPP safety and reliability, such as the upgrading of plant procedures, systems and organizational structure, as well as human resources and performance management. The Executive Summary of the Guidebook is available in English, Spanish, Russian and French. "SAT IAEA 2.0" software is an electronic version of the IAEA Guidebook on "Nuclear Power Plant Personnel Training and its Evaluation".

Currently the IAEA NPES is carrying out a broad range of activities aimed to assist in improving the NPP personnel performance and training through accumulation and dissemination of good practices in the following fields:

- Authorization of control room (CR) operators, with emphasis on the use of CR simulators;
- Training activities for NPP decommissioning phase;
- Management and integration of key factors affecting human performance of NPP personnel;
- Upgrade and modernization of NPP training simulators;
- Use of training approaches, techniques and tools to increasing of NPP personnel training effectiveness;
- Assessment on NPP personnel training programmes;
- Training programmes for the next generation of NPPs.

Future activities are ultimately derived from the identification of actual needs of Member States. These needs are identified through various mechanisms explained in the next section of the paper.
NPES activities, for the years 2006-2007, in the field of human performance and personnel training are planned to cover:

- Developing attitudes and professionalism of NPP personnel;
- Quality management of NPP personnel training;
- Increasing training effectiveness;
- Improving training and performance of NPP maintenance personnel;
- Training for the commissioning of nuclear power plants;
- NPP Contractors: training and performance management;
- Developing a structure for technical documents and databases related to NPP personnel training and human performance improvement;
- Effective knowledge management systems for NPP operating organizations;
- Information exchange on national NPP personnel training and qualification programmes.

10. Facilitating the Information Exchange

The IAEA has established a number of mechanisms to facilitate information exchange in the nuclear industry regarding human performance improvement. One of the most useful and successful has been the IAEA Technical Working Group on Training and Qualification of Nuclear Power Plant Personnel (TWG-T&Q). This Working Group has been in existence since 1994. It has dual, complimentary roles; to facilitate information exchange in the subject area among the 30 IAEA Member States with operating nuclear power plants, and to provide recommendations regarding IAEA activities in the subject area that would be of the most benefit to Member States. In addition to regular meetings of the TWG-T&Q Members, the Agency also uses these Members as a resource for distributing information and for seeking review and comment regarding draft documents. Recently, the IAEA put into service the ENTRAC E-Catalogue, which is a web-based tool for information exchange regarding training and qualification of nuclear power plant personnel. It currently provides the following:

- Information on Nuclear Training Centres including living data on NPP personnel training and links with the local web pages;
- A calendar of IAEA training related events;
- Access to related publications of the IAEA;
- Links to other related web sites.

It is intended that the ENTRAC E-Catalogue be enhanced in the future to provide additional capabilities for information sharing and exchange among nuclear industry training centres and personnel providing training for NPP personnel. ENTRAC users access it through: entrac.iaea.org.

11. Cooperation

The IAEA cooperates with other international organizations and national agencies in the fields of human performance, human resource management and personnel training. The following are examples:

- World Nuclear University (WNU). The IAEA is one of the founding members of the WNU (with the World Nuclear Association the lead organizaton). The IAEA is contributing training and reference materials to WNU, including the use of INIS as a search tool for non-conventional literature on nuclear technology and other relevant topics.
- World Association of Nuclear Operators (WANO). The IAEA and WANO meet regularly to discuss and coordinate their activities, including those related to training courses and workshops.
U.S. Department of Energy (DOE). The IAEA and U.S. DOE have collaborated on a number of activities related to training of NPP personnel, including projects to transfer experience and knowledge in central and eastern Europe related to implementation of SAT, Emergency Operating Procedures (EOP) training, and control room simulator development and use. This collaboration has helped to provide a consistent message and avoid unnecessary duplication of resources.

National and Regional technical cooperation (TC) Projects. For those IAEA Member States with operating NPPs, or considering initiating nuclear power programmes eligible for TC assistance, the Agency has provided a wide range of support in areas including infrastructure development, manpower development, and training design, development, implementation, and evaluation using SAT. In many cases, national and regional training courses and workshops have been jointly developed with and hosted by national training centres.

12. Key Considerations

We would like to conclude this paper with a few evident but important statements:

One of the main objectives of human resource management activities, including training and education, should be to achieve high standards of human performance. NPP personnel competence is a necessary, but not sufficient, condition to achieve high standards of human performance.

Training should be considered as an investment rather than a cost.

While continuously developing plant systems, equipment and software, and maintaining NPP personnel technical expertise, knowledge and skills, we should not forget about such contributors to safety and efficiency as the personnel attitudes, professionalism and ‘soft skills’.
REFERENCES


