Response to the Challenges of Technological Change on a Safeguards Equipment Support Organization: Design of a Performance-Based Training Program

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Abstract

In this paper we examine the challenges facing the International Atomic Energy Agency's (IAEA) maintenance and technical support infrastructure as a result of rapid technological change. The IAEA has been striving to accommodate a progression to newer, digital, computer-based technologies. The rate of change of new technologies has been accelerated by the IAEA's efforts to strengthen safeguards with the use of unattended and remote monitoring technologies. The strengthened safeguards system that relies on these newer technologies requires new knowledge, skills and abilities on the part of the inspectors, engineers, technicians, and other technical support personnel. The U.S. Support Program to IAEA Safeguards is assisting the Agency in responding to these challenges by developing a long-range training program for the technicians assigned to the Department of Safeguards Section for Equipment Installation and Maintenance (TIM).

I. INTRODUCTION

This paper discusses the need for enhanced and coordinated technician training and describes the training program analysis and design work completed to date. The project team identified and prioritized job performance requirements for maintenance technicians, and then developed a training strategy to address the following: evolving safeguards equipment technology, strengthening technician skills for dealing with unanticipated equipment problems, quickly and effectively sharing lessons learned among the maintenance technicians, and limited budgets and time available for training. The design process yielded a training course that specifies training topics sequenced in a manner conducive to adult learners and training units of instruction, both knowledge- and skill-based, with discrete learning objectives and performance standards. This information will form the basis for developing focused training materials during the training development and implementation phases of the project. Opportunities for the safeguards community to collaborate and support planned training initiatives will be offered in subsequent discussions.

II. BACKGROUND

The IAEA currently uses more than 110 different types of safeguards systems, with a broad range of applications and technologies. The technicians assigned to TIM are responsible for providing comprehensive support for these systems during equipment acquisition, setup, testing, calibration, installation, performance monitoring, routine maintenance, troubleshooting, fault diagnosis, repair, and redesign.

Safeguards equipment is generally developed specifically for safeguards applications, but in some cases, commercial equipment is modified to meet safeguards application requirements. The development processes often do not include the quality control mechanisms or production testing required to achieve fault-free products, and technical documentation is seldom of a professional quality. Attention is often concentrated on component design, and system engineering is frequently lacking. The complexity and evolution of safeguards approaches often requires extending and modifying original user specifications. The harsh environment of nuclear
facilities often challenges both the equipment specifications and the user's abilities, resulting in performance aberrations that are difficult to predict and diagnose. Safeguards consequences of equipment malfunction are often costly both financially and politically, placing great importance on superior performance and extreme reliability. The worldwide distribution of safeguards systems, nuclear facility access restrictions, and time constraints at facilities make support logistics complicated and place significant pressures on technical staff. These "facts of life" associated with safeguards equipment require special attention to technician qualifications, training, and technical aids.

Technicians are not generally subject to the short-term contracting policies applied to Agency professional staff; therefore, on-the-job (OJT) training and institutional knowledge are a significant part of a technician's qualifications. However, the fast evolution of technology, particularly associated with digital systems and computer-controlled devices, means that both theoretical and practical training are essential for technicians to provide effective support for newly implemented equipment. Because of the high probability that equipment faults can stem from design or system engineering deficiencies, or be environment-induced, the technician must have the capability to troubleshoot, test, and diagnose on a far broader scale than is required of commercial or industrial product support staff. For many safeguards systems that are installed or resident in nuclear facilities, the technician has neither the Headquarters instrumentation and test resources nor access to supervisors or technical experts. The technician training programs should be specifically tailored to take these aspects into consideration.

International Safeguards is changing in many ways, with one aspect being a greater reliance on state-of-the-art technologies. Eight countries approved the implementation of remote monitoring technology that is dependent on digital, computer, and data communications technology. These countries include Canada, Japan, Belarus, Ukraine, Switzerland, South Korea, Taiwan, and South Africa. Implementation of remote monitoring is complete in Switzerland and South Africa, and underway in the other countries. The remote monitoring initiative allows the timely and efficient collection of International Safeguards data. These programs should result in a reduced reliance on Safeguards Inspector visits and an increasing reliance on the IAEA's technical support staff to maintain the systems.

III. NEEDS ANALYSIS

During this project, analysts assessed the applicability of training as a measure for improving the effectiveness of safeguards equipment support. Training is not the only method for improving the effectiveness of job incumbents. Other measures, such as improved procedures and complete technical documentation, accurate job aids, and effective process control also improve job performance. For maintenance technicians, however, training is being delivered using an informal master-apprentice methodology that is inadequate for addressing the technicians' needs.

A. Changes in Technology

The team identified several circumstances that affect the ability of the technicians to perform all of the tasks comprising the safeguards technician's job description. First, radical changes in technology are being seen in new generations of safeguards equipment. The rapid transition from analog to digital technology is apparent in the design of new surveillance systems. In addition, new systems for surveillance, unattended monitoring, and remote monitoring applications incorporate complex computer controls. These computerized systems, frequently assembled in multiple configurations and with unique settings and performance attributes, require the technicians to have a system administrator's knowledge of the computer operating system. The maintenance technicians are well-trained in analog technology, but they do not have the education, training, or experience to independently maintain the next generation of safeguards equipment, nor are they positioned to learn the new technology in the depth required without the benefit of formal training.

B. Amount and Diversity of Safeguards Equipment

Other factors that influence the training requirements of the technicians include the amount and diversity of safeguards. TIM is responsible for many different types of safeguards systems and major components, many of which can be assembled in multiple configurations or are one-of-a-kind installations. In addition, the equipment is supplied by many different vendors from several different countries and represents a continuum of technological progress.

One way to address this problem is by standardizing equipment, which is difficult; however,
because of the way systems are developed and acquired. Member State Support Programs, for instance, militate against standardization by promoting the products of the respective country. Other factors, including the need to address specific facility configurations, such as on-load refueled reactors, add to the inventory of safeguards systems. The amount and diversity of the equipment for which TIM is responsible warrants a formal, continuing training program to maintain technician competence across a broad range of evolving systems.

C. Development and Acquisition of Equipment

Another aspect of the development and acquisition of equipment affects the performance of safeguards equipment in the field. The typical process for the transition of new systems through the Agency includes formal administrative stages of development or acquisition (Category “C”), evaluation (Category “B”), and then to a stage designated approved for safeguards use (Category “A”). This process does not appear to formally address the new knowledge and skills required of the technicians when the system is finally approved for use and transferred to TIM. The technicians of TIM may be involved in the development phase to varying degrees, but the in-depth expertise and knowledge of the system’s operating history reside in Cost Free Experts (CFEs), contracted vendor staff, and members of the Section for Equipment Development Support (TED). Ideally, the TIM technicians would receive formal training on new systems shortly before the system is approved for routine use, and then selected technicians would work systematically with the CFEs and contracted vendor staff to transfer the responsibility for the new system to TIM. Even if circumstances prevent the process from being formalized, the need for initial training on new systems is essential, and the training should occur before the system is transferred to TIM for support. Once equipment is transferred to TIM, then periodic training is necessary to increase or maintain staff proficiency.

D. Organization and Assignments of Technicians

In addition to training needs associated with advancing technology and with the implementation of new safeguards systems, the organization of the TIM technicians and their assigned responsibilities also help to determine the training requirements. The technicians are organized into three units—Surveillance, NDA, and Unattended Radiation Monitoring. Each of the units is responsible for specific equipment, and within the unit, the equipment is typically assigned to one or two system experts. This practice tends to reduce the training needs of the technicians as a whole, because one or two technicians can maintain proficiency on their assigned systems through job-related activities. However, combining narrow, equipment-specific expertise with minimal training increases the organization’s vulnerability to employee turnover, illness, or injury, and limits the ability to respond to cyclic demand for technician support. Although each technician does not need to develop or maintain comprehensive, in-depth expertise on all systems, the job analysis showed that all of the technicians should be familiar with the systems outside their own area of expertise. The technicians are expected to provide support to inspectors in the field across a broad range of systems and equipment, as well as performing assigned tasks in the field that do not require expert knowledge. These job requirements indicate the need for introductory training on selected systems, as a minimum.

E. Summary of the Training Needs Analysis

The project team concluded that a formal training program for TIM technicians should be a major part of the Agency’s efforts to increase the cost-effectiveness of safeguards systems’ support. Although there is very little turnover in the TIM technician work force, there is an urgent need for training in computer technology as it relates to the new generation of safeguards systems and a concurrent need for training on the new systems themselves. Additionally, continuing training is required on the most important Category “A” systems and associated technology.

IV. STRATEGY FOR TRAINING PROGRAM DESIGN

The training analysts identified the new systems and advanced technology that will be added to the TIM technicians’ job responsibilities in the near future. In addition, the team identified the activities and associated Category “A” systems that comprise the current maintenance technician’s responsibilities, and then determined the need for training on these activities and equipment based on the difficulty, importance, and frequency of related problems encountered on the job. In total, the training needs based on new systems and those based on Category “A” systems in use provide the basis for the TIM Technician Training Curriculum.

A. Development of the Training Approach
In designing the TIM Technician Training Program, the project team selected a training approach that addresses the organization of the technicians and the section’s practices for assigning responsibilities, the working environment, stability of the technician work force, and the resources available at the Agency to develop and deliver training. The training approach selected for the TIM Technician Training Program involves developing two distinct curricula for training technicians—an initial training curriculum and a continuing training curriculum. Initial training is focused on developing new capabilities among the TIM technicians and continuing training is focused on retaining expertise on Category “A” systems and on current technology.

B. Initial Training

Initial training needs are closely associated with advancements in technology and with new safeguards systems. The Server Digital Image Surveillance System (SDIS) is a good example. SDIS is a local area network (LAN) with a computer server running Windows NT and multiple DCM-14 camera units operating on the LAN as clients. Further, the operational mode in which SDIS is used, for either unattended or remote monitoring, has a significant effect on the operation and maintenance of the system. SDIS is currently being field-tested, but when it is approved for use, installation and maintenance of SDIS will become the responsibility of the TIM technicians. To install and maintain this system reliably, the technicians will need initial training on the computer technology that is incorporated in the equipment design and the Windows NT operating system, as well as the equipment-specific tasks comprising the technician’s job responsibilities. Unlike Category “A” systems that may have a long history of use by the Agency, there is little expertise among the technicians on Category “B” systems, so when these systems are transferred to Category “A,” training must be provided to the TIM technicians as the first step to establishing the required maintenance capability.

The development and delivery of initial training typically requires support from outside the Agency. Vendors, national laboratories, and professional training organizations can provide the subject matter expertise, resources, and instructional capabilities to deliver the required formal training. Equipment vendors, in particular, have an in-depth knowledge of the design and development of new systems. Further, the vendors should have extensive technical documentation and sufficient experience from the equipment design and field-testing phases of development to be able to provide comprehensive training on specific safeguards equipment and systems. Initial training will comprise formal training courses of a few days to two weeks delivered by Agency consultants and contractors. Each course will cover learning objectives provided by the Agency and will include applicable classroom and practical training. The scope and depth of the training should be sufficient to enable technicians to understand the construction and operation of the new system, to perform standard installation and maintenance tasks, and to work effectively on the system while learning through experience.

After initial training has been delivered, the system should be added to the continuing training program discussed below. The TIM technicians may not be able to master the new system based solely on initial training, but the combination of initial training, experience with the system, and periodic input from vendors for problem resolution will soon establish the required subject matter expertise.

C. Continuing Training

In addition to retaining expertise on Category “A” systems and on current technology, continuing training supports the transfer of expertise from system experts to other TIM technicians, provides overview training for non-system experts, and supports “as-needed” training for infrequently performed tasks. The content for continuing training should be supported by existing technical documentation and by the knowledge of system operating history of the technician work force, even though the expertise may be confined to a single person.

Continuing training also provides a mechanism for collecting, retaining, and disseminating new information on safeguards systems. During the period after a new system is approved for Category “A” use, for instance, modifications of equipment, revisions to procedures, and changes to installation and testing practices are common. These should be incorporated into continuing training materials and systematically provided to the appropriate technicians.

In designing the continuing training curriculum, the analysts noted that the work force is characterized by deep, but narrow system expertise because the technicians are divided first by units and then assigned responsibilities for specific equipment. The assignment of a specific system to a technician was essentially arbitrary because there is no pervasive
hierarchy among the systems requiring that one be mastered as a pre-requisite to learning another. The organization of the technicians by unit and the assignment of systems to specific persons also imply that the training program should be easily tailored to individual training needs, because relatively few technicians may require in-depth training on a system at any one time. Because of this, the training plan is very flexible, allowing management to identify required training for individuals or groups based on their assignments, while also providing the structure and resources to support an individual technician’s self-directed efforts to increase his or her understanding of safeguards equipment.

The continuing training curriculum uses units of instruction designed for training individuals or small groups of technicians and is based on self-study augmented by a formal master-apprentice approach to OJT. Self-study units of instruction offer several advantages over group training. Self-study training materials, for instance, are also suitable for group training venues. The opposite, however, is usually not true. The student materials used with lectures and seminars are designed to be used with a formal presentation by an instructor, so they seldom provide either a “stand-alone” sequence of learning activities or a comprehensive student reference. Self-study materials, however, can easily be adapted to formal group training presentations by employing an instructor guide to support the formal presentation and using the self-study materials as a student reference. Using this approach, system experts could deliver formal training to small groups of TIM technicians, when required.

In addition to the versatility of self-study training materials, there are other considerations affecting the choice of self-study units of instruction as the basic building block for continuing training. First, training delivered via lectures and seminars is only cost-effective if there are enough attendees to warrant the expenditure. The technicians are assigned specific responsibilities as system experts. Because each system typically has only one system expert and one backup system expert, there is little need to simultaneously provide training to several technicians on the same system. In addition, the technicians do not work on a closely coordinated schedule. The work requirements for one safeguards system or type of system are unrelated to the work requirements for others, so it is difficult to schedule formal training for delivery to a group of technicians without disrupting ongoing work within TIM.

Second, as adult learners, the TIM technicians are typically self-motivated to learn what they require on the job, so a set of self-study materials provides a valuable resource for individual study and subsequent reference as a job aid.

Third, self-study units of instruction organized by system offer flexibility in designing customized training programs for individual TIM technicians. By selecting applicable units of instruction from the continuing training program, TIM management can formally designate a progression of learning activities that support new system expert assignments within TIM, provide for professional development, or support short duration training of technicians from IAEA field offices.

Fourth, there is no training staff within TIM, nor are there personnel with instructor experience, so a program based on formal training presentations would require additional staff or new collateral duties for existing staff, as well as training on instructor techniques. Given the Agency’s zero-growth policy and increasing work scope for the technicians, extensive use of formal training presentations is not recommended for the continuing training curriculum.

Finally, materials developed for self-study are more suitable for delivery via technological means than other, less comprehensive training materials. The Agency currently plans to deliver TIM technician training via traditional means, but in the future it may need to deliver the material to a larger, distributed population via CD ROM, the Internet, or an intranet. Because self-study materials include scripted training activities and do not rely on an instructor, they are easily adapted to alternative delivery media.

D. Training Materials for Continuing Training

The project team recommended developing an instructor guide and a student guide for each unit of instruction in the continuing training curriculum. The instructor guide supports the delivery of training by a system expert and covers classroom seminars, laboratory sessions, and OJT. The instructor guide helps to standardize training content and provide assurance that the training delivered is essentially the same every time, regardless of the instructor, and that no required content is omitted. Instructor guides also provide a mechanism for management review and approval of training content as well as a means to document the development of training materials.
The student guide is a reference for the student. It contains equipment and task-specific information organized and illustrated to support ease of learning and to enhance retention. For the TIM maintenance technicians, the student guide should be written in a style that promotes clear understanding by users who speak English as a second language. The clarity should be attained through simplified grammatical constructions and vocabulary while still providing all of the required technical content, regardless of its complexity. The student guides should be designed not only to support formal training delivered by system experts, but also to provide a comprehensive reference that supports self-study by the technicians. In addition to a comprehensive reference, student guides should identify the learning activities intended for the student, including items such as reading assignments, study questions, and practical exercises.

V. THE CASE FOR THE SYSTEMATIC APPROACH TO TRAINING

Over the past 25 years, the world’s concept of quality has undergone fundamental change. In the past, it was routine to inspect a component or product just before shipment and to discard those items that did not meet some predetermined standard. Managers and workers assumed that rework of defective products was part of the production process and that the goal of quality assurance was solely to minimize the number of defective products shipped to customers. This method of “inspecting quality into a product” was reactionary and did not attempt to systematically identify the weakness in the process that produced the defective part in the first place.

Modern quality assurance standards, such as ISO 9000, are proactive and focus on the entire process by which a particular product or service is created in addition to the end product itself. Industry learned by experience that quality is built into a product through a process which can consistently and efficiently produce the desired results. Certainly the end product of any quality process is inspected—be it a car, a television, or a TIM maintenance technician—but it should always be inspected within the context of the process which created it. Modern quality assurance programs typically measure quality processes using four criteria: 1) the end product must be able to perform its design function, 2) the process must be highly repeatable, 3) the process should consume the fewest amount of resources possible, and 4) the process should incorporate a mechanism for continuous improvement whereby product defects are identified and the root cause of those defects is corrected. Quality assurance standards, therefore, may vary in the manner in which these criteria are measured or documented; but in the final analysis, they are still attempting to measure the same things.

Training is an effective means for improving human performance. However, some training approaches suffer from the same reactionary approach that characterized the traditional approach to quality management—namely responding to near-term problems without attempting to identify or correct the root cause of the problems that generated the training need. Although it may be appropriate in some circumstances to conduct training on an ad hoc basis to address short-term problems, training programs based solely on this approach will most likely result in a program which is less effective than one that takes a long-term, planned approach to improving human performance. Organizations that desire to implement a long-term training program should look to those training approaches that adhere to the principles of quality assurance.

Our team proposed to develop the Agency’s Maintenance Technician training program in accordance with the Systematic Approach for Training (SAT). SAT is a performance-based training system that is used throughout the world to develop training programs. SAT has been proven effective at training workers to perform job-related tasks safely, reliably, and cost-effectively. SAT identifies key knowledge and skills required for job performance and designs a course curriculum to present the information to the student in the most effective training setting available—whether it is in the classroom, in a laboratory, on the job, or by self study modules. SAT is popular in industrial and technology-based industries because SAT is founded on the same principles as modern quality assurance programs.

SAT forms the basis for developing a quality training process because it meets the four criteria for quality processes. SAT designs training courses with the end in mind. The analysis phase focuses on the job an individual must perform, and then identifies what that person must know and what skills they must possess to perform that job. In this sense, SAT starts by asking the question, “What is the design function of the final product (the trainee) and how do we ensure that the end product will be able to perform its design function?”

During the design phase, subject matter experts develop learning objectives and test items to ensure that everyone is trained in the same manner and
performance is measured using the same evaluation criteria. This makes the process highly repeatable. SAT identifies training for only those tasks that are important for job performance. This helps to minimize the consumption of resources; in this case the time and money spent developing and presenting training materials and the time students spend in training. Finally, SAT incorporates an evaluation phase that measures how well the trainees are performing their jobs and then identifies how the training process might be changed to correct any training deficiencies. This helps to ensure that the cause of problems is identified and corrected and increases the confidence in the system.

Using the SAT process for developing a maintenance-training program, the Section for Equipment Installation and Maintenance will benefit from the value of an effective training program. The program is effective because it is based on job performance requirements with standards established by Agency management, it is designed to be cost-effective over the long-term, and is flexible and responsive to the changing needs of the maintenance technician’s job position.

VI. CONCLUSION

The incorporation of digital technology and advanced communication systems into safeguards equipment poses a significant challenge for TIM maintenance technicians. These technicians, whose education and experience are based on analog technology, must be able to install, diagnose, troubleshoot, maintain, and test these new digital systems on a broad scale because of a high incidence of equipment design problems and environmentally-induced failures. An effective approach in meeting this challenge is to implement a performance-based training program. A flexible training program based on the principles of the Systematic Approach to Training can provide TIM technicians with the tools required to learn the new knowledge and skills necessary to maintain modern digital safeguards systems. Further, based on our experience with the TIM training program, we are confident that the SAT model can be applied to other safeguards programs to address human performance problems associated with changing technology.

We hope that our paper will motivate program managers to reflect upon the role of training in improving the effectiveness of safeguards programs. We consider it important to share our experience and expertise with the entire INMM community so that we can all more effectively serve the IAEA Department of Safeguards as they perform their important mission. Ultimately, a strong commitment to training can greatly contribute to the effectiveness of all our nuclear materials management programs.

VII. ACKNOWLEDGEMENTS

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VIII. REFERENCES