IAEA
International Atomic Energy Agency

IAEA TECDOC SERIES

No. 2082

Use of a Graded Approach in the Application of Systematic Approach to Training for Facilities and Activities

USE OF A GRADED APPROACH IN THE APPLICATION OF SYSTEMATIC APPROACH TO TRAINING FOR FACILITIES AND ACTIVITIES

The following States are Members of the International Atomic Energy Agency:

AFGHANISTAN
ALBANIA
ALGERIA
ANGOLA
ANTIGUA AND BARBUDA
ARGENTINA
ARMENIA
AUSTRALIA
AUSTRIA
AZERBAIJAN
BAHAMAS
BAHRAIN
BANGLADESH
BARBADOS
BELARUS
BELGIUM
BELIZE
BENIN
BOLIVIA, PLURINATIONAL STATE OF
BOSNIA AND HERZEGOVINA
BOTSWANA
BRAZIL
BRUNEI DARUSSALAM
BULGARIA
BURKINA FASO
BURUNDI
CABO VERDE
CAMBODIA
CAMEROON
CANADA
CENTRAL AFRICAN REPUBLIC
CHAD
CHILE
CHINA
COLOMBIA
COMOROS
CONGO
COOK ISLANDS
COSTA RICA
CÔTE D'IVOIRE
CROATIA
CUBA
CYPRUS
CZECH REPUBLIC
DEMOCRATIC REPUBLIC OF THE CONGO
DENMARK
DJIBOUTI
DOMINICA
DOMINICAN REPUBLIC
ECUADOR
EGYPT
EL SALVADOR
ERITREA
ESTONIA
ESWATINI
ETHIOPIA
FIJI
FINLAND
FRANCE
GABON
GAMBIA, THE
GEORGIA
GERMANY
GHANA
GREECE
GRENADA
GUATEMALA
GUINEA
GUYANA
HAITI
HOLY SEE
HONDURAS
HUNGARY
ICELAND
INDIA
INDONESIA
IRAN, ISLAMIC REPUBLIC OF
IRAQ
IRELAND
ISRAEL
ITALY
JAMAICA
JAPAN
JORDAN
KAZAKHSTAN
KENYA
KOREA, REPUBLIC OF
KUWAIT
KYRGYZSTAN
LAO PEOPLE'S DEMOCRATIC REPUBLIC
LATVIA
LEBANON
LESOTHO
LIBERIA
LIBYA
LIECHTENSTEIN
LITHUANIA
LUXEMBOURG
MADAGASCAR
MALAWI
MALAYSIA
MALI
MALTA
MARSHALL ISLANDS
MAURITANIA
MAURITIUS
MEXICO
MONACO
MONGOLIA
MONTENEGRO
MOROCCO
MOZAMBIQUE
MYANMAR
NAMIBIA
NEPAL
NETHERLANDS, KINGDOM OF THE
NEW ZEALAND
NICARAGUA
NIGER
NIGERIA
NORTH MACEDONIA
NORWAY
OMAN
PAKISTAN
PALAU
PANAMA
PAPUA NEW GUINEA
PARAGUAY
PERU
PHILIPPINES
POLAND
PORTUGAL
QATAR
REPUBLIC OF MOLDOVA
ROMANIA
RUSSIAN FEDERATION
RWANDA
SAINT KITTS AND NEVIS
SAINT LUCIA
SAINT VINCENT AND THE GRENADINES
SAMOA
SAN MARINO
SAUDI ARABIA
SENEGAL
SERBIA
SEYCHELLES
SIERRA LEONE
SINGAPORE
SLOVAKIA
SLOVENIA
SOMALIA
SOUTH AFRICA
SPAIN
SRI LANKA
SUDAN
SWEDEN
SWITZERLAND
SYRIAN ARAB REPUBLIC
TAJIKISTAN
THAILAND
TOGO
TONGA
TRINIDAD AND TOBAGO
TUNISIA
TÜRKİYE
TURKMENISTAN
UGANDA
UKRAINE
UNITED ARAB EMIRATES
UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND
UNITED REPUBLIC OF TANZANIA
UNITED STATES OF AMERICA
URUGUAY
UZBEKISTAN
VANUATU
VENEZUELA, BOLIVARIAN REPUBLIC OF
VIET NAM
YEMEN
ZAMBIA
ZIMBABWE

The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

IAEA-TECDOC-2082

USE OF A GRADED APPROACH IN THE APPLICATION OF SYSTEMATIC APPROACH TO TRAINING FOR FACILITIES AND ACTIVITIES

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2025

For further information on this publication, please contact:

Nuclear Knowledge Management Section
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria
Email: Official.Mail@iaea.org

Printed by the IAEA in Austria
March 2025
https://doi.org/10.61092/iaea.kjhb-nkmf

IAEA Library Cataloguing in Publication Data

Names: International Atomic Energy Agency.
Title: Use of a graded approach in the application of systematic approach to training for facilities and activities / International Atomic Energy Agency.
Description: Vienna : International Atomic Energy Agency, 2025. | Series: IAEA TECDOC series, ISSN 1011-4289 ; no. 2082 | Includes bibliographical references.
Identifiers: IAEAL 25-01747 | ISBN 978-92-0-105125-7 (paperback : alk. paper) | ISBN 978-92-0-105025-0 (pdf)
Subjects: LCSH: Nuclear facilities — Management. | Radiation — Safety measures. | Nuclear facilities — Employees — Training of. | Nuclear power plant operators — Training of.

FOREWORD

Training is an important part of any management system for a nuclear facility or activity. Several training models are used around the world to ensure that personnel are suitably qualified to work effectively, efficiently and to the expected level of quality in accordance with the relevant standards. One such model, the systematic approach to training (SAT), has been recognized by the IAEA, and its methodology has been accepted internationally by many nuclear organizations and Member States.

The SAT methodology applies a graded approach that is in proportion to risk and ensures the appropriate level of training, while maximizing the return on investment. In the context of training development, the main criteria for grading the positions, roles and responsibilities are based on the importance of safety, safeguards and security, the magnitude of any hazard or risks involved, the complexity associated with the job or tasks, the life cycle stage of the facility, the programmed mission of the facility and the particular characteristics of the facility. In this approach, application of the management system requirements is most stringent for processes and services with the highest grade.

The graded approach itself is not bound directly with nuclear safety; nevertheless, it is often used to allocate oversight activities for safety related matters and the application of controls, and to determine the appropriate way to comply with safety requirements. In this regard it is important to understand that the graded approach is not used to provide relief from meeting a requirement.

This publication provides an overview of grading principles, criteria and processes and the roles and responsibilities related to the grading process. In addition, it provides information on application of grading across all phases of the ADDIE (analysis, design, development, implementation and evaluation) process, which is a specific implementation of the broader SAT methodology. This publication does not prescribe an approach to grading the application of SAT, but instead provides information supported by experience and practical examples of grading used in Member States. A flow chart providing examples of activities and efficiency adjustments to consider when initially selecting or re-evaluating the grade at which to apply SAT is included as a supplementary file available on-line.

The IAEA wishes to thank all those who contributed to the development of this publication. The IAEA officer responsible for this publication was R. Květoňová of the Division of Planning, Information and Knowledge Management.

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

There are unique characteristics related to safety and security in the nuclear industry. These critical characteristics are considered and analyzed during development, designing and operating stages by defining different grades based on its impact and by applying a graded approach and assigning resources to the most important ones to control and minimize its impact.

This publication supports IAEA Nuclear Energy Series No. NG-T-2.8, published in 2021 [1] on Systematic Approach to Training (SAT) for Nuclear Facility Personnel: Processes, Methodology and Practices by providing guidance and worked examples (in the form of Member States case studies) for the implementation of a graded approach to SAT. The document describes the graded approach in the application of SAT as a challenging process that requires good experience and expertise in the training of personnel. The graded approach needs to be based on consideration and prioritization of nuclear safety risks, as well as health and safety risks to personnel and the environment The most significant benefits from deploying the graded approach to SAT are ensuring both high quality and the effectiveness of training. These make a significant contribution to the safety and performance of nuclear facilities.

The IAEA primary objective and associated fundamental safety principles [2] and standards include the requirement for a graded approach, especially in respect to the assessment of safety aspects and the assessment of radiation risks.

1.2. OBJECTIVES

The objective of this document is to support the publication Ref. [1] and to provide:

- The guidance to understand a grading methodology in SAT;
- The assistance to develop and apply a graded approach in SAT application;
- The tools and criteria for a graded approach in SAT;
- Case studies and practical examples from different nuclear organizations that have implemented a graded approach to SAT.

1.3. SCOPE

In support of Ref. [2] this publication provides practical guidance and examples on the use of a graded approach to the application of the SAT model within nuclear facilities. It is applicable to, but not limited to, the jobs/tasks which have an impact on nuclear, health and safety or environmental operations.

This publication is intended to be used by organizations directly responsible for:

- Nuclear facilities;
- Activities using sources of ionizing radiation;
- Radioactive waste management;
- Radiation protection activities;
- Regulatory organizations;
- Training and human resource managers and specialists.

However, this document could be also useful for the grading of training activities in regulatory bodies, designers, manufacturers, constructors, contractors, suppliers, and technical support organizations.

1.4. STRUCTURE

This publication presents the history and evolution of the SAT methodology in Section 2. This is followed by Section 3, which highlights the importance of the use of a graded approach in the application of SAT for nuclear facilities and activities. Section 4 describes the graded approach in the wider context of the SAT methodology and Section 5 details the grading criteria, its application, and the overall grading methodology. Section 6 provides case studies and finally, Section 7 provides a summary of this document and conclusions.

2. HISTORY AND EVOLUTION OF SAT

2.1. HISTORY AND EVOLUTION

SAT was originally promoted in the nuclear industry, in the years after the Three Mile Island (TMI) accident in the USA, as a means of ensuring safety through the proper training of personnel. Consequently, it came to be seen as more of a regulatory compliance tool. It was widely adopted for the training of operators in those early years but was less commonly used for other staff. During the early deployment of SAT for operators, significant resources were utilized in the detailed analysis of training needs and this, combined with the perceived compliance nature of SAT, led to it being seen as a training ‘burden’ by many in the industry. ADDIE phases and processes supporting SAT framework were first designed by the US Air Force as a five-step model and then converted to ADDIE by US Army at the Centre for Ed Tech at Florida State University in 1975.

The benefits of effective SAT have become clear with time, and it is now broadly accepted that the use of SAT has contributed significantly, among other factors, to the improvement in the global capacity factor of NPPs, from an average of around 60% in the early 1980s to more than 80% in the early 2000s [3]. As a result of this success, SAT has been deployed across a much wider range of disciplines in nuclear facilities and it has become the recommended training approach across the nuclear industry.

This broader application of SAT has further increased the workload of training functions and brought additional focus on the analysis phase of SAT, since this is where a significant proportion of the overall resources needed for SAT are deployed. One result of this is that many organizations now include an initial ‘needs analysis’ step in the process, to confirm whether training is actually (part of) the solution to an identified problem or performance gap, before carrying out the ‘analysis’ phase of SAT. In addition, many organizations have sought less resource intensive approaches to carrying out the analysis phase, especially for those job positions and tasks which are considered to have less safety significance.

Another key evolution of SAT has been the involvement of the line organization in the identification of training needs and the development of solutions, as it is they, and not the training organization, who are responsible for the competence of their staff. These, and other important lessons learned, are detailed in the publication Ref. [1], Systematic Approach to Training for Nuclear Facility Personnel: Processes, Methodology and Practices, which this technical document (TECDOC) has been developed to support.

3. DEFINITION AND IMPORTANCE OF A GRADED APPROACH

3.1. WHAT IS A GRADED APPROACH?

A graded approach can be defined as the process of proportioning resources in a manner that results in the highest safety benefit (or other targeted objective), whilst not adversely affecting the quality of the training programme or achievement of the required level of competence.

Implementation of the graded approach to SAT is one where the level of detail and formality in each stage of the ADDIE process, the supporting documentation, the actions taken (use of committees etc.), continuing training programmes and implementation of training and related facility performance measures is commensurate with:

- The relative importance of safety, safeguards and security;
- The magnitude of any hazard or risks involved;
- The complexity associated with the job/tasks;
- The life cycle stage of a facility;
- The programmed mission of a facility;
- The particular characteristics of a facility.

A graded approach might be applied to any position which does not have a significant impact on the safety or commercial viability of a facility Ref. [1].

The SAT and ADDIE process are fully described in Ref. [1] and in this document. For any job or task identified as being at grade 1 (Section 5.2), the process described in Ref. [1] should be followed. However, the entire process described in this document represents a graded approach and the first step of the process described in Chapter 5, where the appropriate grade for a job/task is assigned, is still considered part of the graded approach, even if the agreed grade is grade 1.

3.2. WHY USE A GRADED APPROACH?

It is important to remember that the aim of training programmes within any nuclear facility is to develop a competent workforce that can efficiently and effectively undertake the jobs/tasks assigned.

In recent years, the potential of SAT as a performance improvement tool, rather than just a regulatory compliance tool has been increasingly recognized. However, with the growth in deregulation of nuclear energy in many countries, and the need for it to be more commercially competitive, the costs of training are being increasingly challenged.

In the early days of SAT, excess training (over-training, above the identified requirement) was, if anything, considered to be beneficial, now it is seen as an unnecessary cost. Excess training may also have a negative impact on trainees in terms of motivation and their perception of the relevance of training. Historically, there has also been a tendency to overestimate the safety significance of roles when developing their training programmes, resulting in potential excess training with its associated resource and cost implications.

The application of SAT also generates significant amounts of data ranging from analysis databases, task to training matrices, approved training materials, records of trainee attendance and performance, etc. The management of this data has added to the cost of training, although this has been improved in recent years by the development of a number of commercial training management software systems.

If SAT is inappropriately used it can be perceived as:

- Overly bureaucratic: involving many forms and signatures, placing unnecessary demands on key personnel’s time;
- Resource intensive: facilities and trainers;
- Overly complex: programme analysis, development, management and maintenance;
- Limitations: providing limited benefit over other training approaches;
- Costly: improvement in facilities objectives and key metrics do not demonstrate a return on investment.

Hence a structured, graded approach is needed, which helps to ensure that staff receive only that training which they need to perform their roles safely and efficiently. Adopting a graded approach to SAT may provide the following benefits:

- Reduction in the overall training requirement and hence cost of training;
- Effective use of training resources due to streamlined application of ADDIE steps;
- Streamlining the management of the training process and the amount of training data to be maintained;
- Increased ownership by line management due to the reduction in the resources required to support training and reduced time of personnel being released for training;
- Increased ownership by trainees as training is focused on job needs and less time is spent in training.

Successful use of SAT by multiple Member States over many years has resulted in the design and development of an extensive array of training materials (including job and task analyses; objectives, lesson plans, examination tools, etc.), applicable to many of the nuclear technologies currently in use around the world. This library of existing materials, documenting the results of all phases of SAT, provides a reliable starting point to address training needs at both existing and new-build facilities. The use of existing materials as a starting point to address newly identified training needs is a key element of the graded approach to SAT. Member States are encouraged to:

- Seek out existing materials that may provide a starting point for developing new or revised materials to meet training needs;
- Share existing materials with other Member State facilities as allowed by applicable security and proprietary requirements.

3.3. GUIDANCE FOR A GRADED APPROACH

One of the biggest challenges in developing guidance for a graded approach is that each organization has its own historical approach to SAT development and different priorities for adopting a graded approach, depending on its plans. For example, adopting a graded approach provides many benefits for a new organization with many years of future facility operation to realize those benefits, whereas an organization approaching its decommissioning phase, will focus on an overall reduction in training, while not wanting to expend significant resources on developing a graded approach.

As mentioned previously, the data generated by the SAT process, and the approval process within SAT, can be a challenge to manage and maintain effectively. Hence, an important aspect of applying a graded process is to identify where the ‘bureaucracy’ of SAT can also be graded appropriately.

Even in a graded approach, feedback continues to be an essential element and it is important to ensure that there is adequate feedback built in to check that any downgrading of the level of SAT is appropriate and produces the desired results.

4. GRADED APPROACH IN THE WIDER CONTEXT OF SAT METHODOLOGY

Many of the more mature nuclear industry organizations have conducted some form of grading of SAT within their training programmes, driven by reorganization, deregulation, cost pressures, etc., based on their own experience and needs. The process described in Chapter 5 tries to consolidate that experience and is supported by the case studies in Chapter 6.

It is important that senior and line managers understand the main principles and benefits of SAT and the utilization of a graded approach and support its implementation within the organization. Assignment of experienced line managers or subject matter experts as champions able to describe the benefits of, and promote, the graded approach within the organization would highlight their understanding and acceptance of the graded approach. The champions within their designated area assess the current status quo in the organization and work out the way to improve it. For example, a training champion will actively look for skills gaps and approach management with ideas for how to fill them.

The SAT methodology has been proven to deliver significant benefits in developing the required personnel capabilities to operate a nuclear facility, delivering improved performance of the facility [1], a reduction in safety related incidents, and reduced personnel injuries or accidents. These benefits can be realized across all areas, from operations to administration. However, correctly grading the application of SAT is essential to ensure that the balance of cost and resource is targeted at the most appropriate areas.

Within a nuclear facility there are numerous jobs/tasks that can be shown to present a minimal hazard or threat/risk to nuclear, environmental, and/or personnel safety and where the full application of SAT provides limited or no benefit; and thus delivers a poor return on investment for the benefits derived. All positions within the nuclear facility should be assessed to determine what level of a graded approach to SAT can be adopted.

The most significant benefits from deploying a graded approach to SAT are ensuring both the quality and the relevance of the training continue to support the development of the required competence without introducing knowledge aspects into the training which add no value. It is therefore important that, when applying the Graded Approach, appropriate oversight is maintained to ensure the original intent of training is being met.

5. GRADING CRITERIA AND METHODOLOGY

5.1. GRADING METHODOLOGY

To ensure the appropriate priority of effort and resource is undertaken consideration of prioritizing roles or positions, based on risk to safety, may be appropriate. The graded approach is then applied at task level during the ADDIE stages of SAT.

The grading methodology consists of the following three key stages:

- *Determine if training is the best solution*. The first step is to determine whether training is an appropriate solution to address the identified problem. Other solutions may provide a quicker and more cost-effective answer (e.g., develop or enhance a procedure, more direct supervision, changing the task, on job mentoring, etc.) and should be considered. Human performance issues can give rise to problems, which if not fully understood can lead to unnecessary training for the consequence rather than the root cause, being developed and delivered. It may be that through this initial investigation it is determined that the person or persons know how to do the job/task but decide not to undertake it in the prescribed way. More training on how to do it will not necessarily help and the root cause (or outcome of event analysis) and identification of the real problem needs to be understood before training, if any, is developed.

- *Propose the grade*. Once it has been determined that training is the solution to address the identified problem, confirmation of the proper grade of SAT (refer to section 5.2 and 5.3) for the job/task should be undertaken by an initial analysis. This will then determine the requirements for the next stage of the analysis and the subsequence stages of the ADDIE process, level of documentation, records management, authorization route, etc. During this initial analysis consideration needs to be given to the hazard posed, risk presented and complexity of the job/task. To undertake this stage, sufficient information needs to be gathered (procedures, interviews with personnel with sufficient knowledge or expertise in the area, safety or regulatory requirements, operating instructions, etc.), to enable an understanding of the role and responsibilities required. A widely used approach, useful at this stage, is to undertake a tabletop exercise with a small group of experts, knowledgeable in the area being reviewed, coordinated by training expertise in the implementation of the graded approach to SAT, using the data gathered as input. When undertaking the initial review one or more tasks within a role may be identified as complex or posing a significant risk/threat and should be treated accordingly with a full SAT implementation [1]. This should not dictate that the entire role is necessarily treated in this way. The remainder of the job/tasks which are of a lower order of significance can adopt a lower grade.

- *Implement training material development, grading SAT as required.* Develop training material implementing graded approach to SAT, applying the level of detail to each step of the ADDIE process appropriate to the identified grade. Consider documentation requirements, authorizations, and approval process which should be adjusted to reflect the grading.

Once completed it is important to capture the rationale taken for grading and the level being applied, i.e., what grading has been applied, how was the grade decided and how was the grade approved. This will ensure visibility of process and evidence of methodology.

5.2. GRADING CRITERIA

The following SAT grading criteria provides some generic guidance against which an assessment of the appropriate grade of SAT implementation required can be made. As described in Ref. [1] SAT may be applied at three basic grades. It is important to note that although the below grades specifically refer to nuclear safety and reactivity, these apply also for other areas as listed in the criteria and as detailed in the flow chart, Fig. 1, which can be downloaded from the electronic version.

— *Grade 1:* Positions, roles and tasks that carry an immediate and direct impact on nuclear safety and reactivity. Full implementation of SAT as described by Ref. [1] for all activities and tasks;
— *Grade 2:* Positions, roles and tasks that carry a limited or discrete and specifically identified nuclear safety and reactivity risk. Full implementation of SAT as described by Ref. [1] for specific activities and tasks;
— *Grade 3:* Positions, roles and tasks that have no direct or indirect impact on nuclear safety or reactivity but are important functions in a nuclear facility. Limited implementation of SAT where required.

5.3. APPLICATION OF GRADING CRITERIA

The most practical example of the application of a graded approach to SAT is the use of existing materials as a starting point for addressing new training needs. Existing materials can include training needs, job, and task analyses; objectives; examination tools; lesson plans, etc. Training materials developed properly and used over a long period of time have the advantage of incremental improvements based on student feedback, comments from management observations, incorporation of corrective actions and operating experience. Not using these existing materials when addressing a new training need can result in losing the benefit of all of this prior experience. In many cases, the responsible use of a graded approach to SAT may be the best way to achieve a high quality, new product.

To provide the appropriate level of SAT grading for the job/task the following subject areas may be considered as an aid in establishing an understanding of the requirements and priority and hence the grade of the roles/tasks. This is not an exhaustive list and examples provided under each heading are for guidance only.

5.3.1. Its Relative Importance to Safety, Safeguards and Security

Grading considerations in areas of:

— *Safety*: From a safety case, what tasks could favour (or not impede) the progression of an event through the PSA (probabilistic safety assessment)? Particularly, for example, those that, if not executed correctly in a given time, would compromise systems, structures, components. What tasks could lead to abnormal conditions, but not to an event progressing through PSA?;
— *Safeguards*: Jobs/tasks that could challenge safety systems. Movements of nuclear material, its accounting and controls (e.g., tasks that directly handle, control or account material, accounting records and internal controls tasks);
— *Security*: A security needs analysis should consider those activities (jobs/tasks) which include cybersecurity, physical security, and information security and the level of risk or threat posed to enable the establishment of an appropriate grade.

5.3.2. The Magnitude of Any Hazard Involved

Examples of areas for analysis:

- The nuclear significance;
- The environmental impact (within and external to the facility);
- Potential to damage the facility;
- Potential for injury of personnel or loss of life;
- Potential for harm to the surrounding community.

Hazard and operability study (HAZOP) assessment reports may provide additional information for the above subject areas to aid prioritization/grading of the jobs/tasks being analyzed.

5.3.3. The life cycle stage of the facility

The stage in its life cycle is the nuclear facility in should be considered as a factor in grading the jobs/tasks. During the different life cycle stages the hazards change as do the staffing requirements with associated knowledge build or retention challenges. During these different stages cost to benefits of training activities plays a greater or less significant role. However, safety cannot be compromised at any of the stages.

For example, any nuclear facility could be considered to be in one of four stages:

- Construction, which could be subdivided into:
  - Initial construction phase: Consideration of what roles the facilities staff will have (oversight of work or part of the construction team);
  - Commissioning: Commissioning is an essential process for the subsequent safe operation of a nuclear facility;
  - Arrival of nuclear material on site: nuclear material arrives on site, systems commissioning is undertaken, new staff recruited in preparation for operation requiring development of new roles and programmes in preparation for operation.
- Facility operation:
  - Facility operating with full complement of staff requiring all facility roles to be staffed with competent personnel. Potentially many years to realize the benefits.
- Facility life extension:
  - In this phase staffing for the extended life span may become more of an issue as knowledge, which needs to be maintained, is lost through attrition. Business case for continued operation becomes more challenging with the cost to benefits ratio being a focus for all activities including training.
- Decommissioning:
  - During this period the cost benefit of training may play a more prominent role in the consideration of the final training grading in parallel with a forward-looking workforce plan. It is important to have a clear picture of the rate of attrition due to retirement, workforce reassignment or leavers. Demonstration of return on investment at this stage of life is critical as the facility is no longer operating and generating income.
- Decommissioning could be subdivided into the following phases:
  - Nuclear material removal from site (i.e., defueling) - requirements to maintain safety systems and management of nuclear material during defueling operations. Regulatory requirements to be met (e.g. nuclear, environmental);
  - Deconstructing facility post removal of nuclear material.

5.3.4. The Mission of the Facility

The mission or objectives of a nuclear facility can aid in prioritizing/grading jobs/tasks according to the following aspects:

- Economy: Commercial constraints that drive operational requirements such as flexible operation (on or off), reduced outage time, optimized equipment maintenance schedule through condition monitoring;
- Reliability: Reduced unplanned outages;
- Availability: On-demand requirements.

5.3.5. The Particular Characteristics of the Facility

The following criteria may be also considered in establishing the grading processes.

- Unique technology or design. Is there adequate external support or do knowledge and skills need to be maintained within the organization;
- Complexity of design or special features developed within the organization;
- Location:
  - Climatic conditions (e.g., extreme heat or cold could change the complexity or importance of certain tasks identified within the facility safety case);
  - Environmental constraints within the facility requiring use of special equipment and/or protective clothing or apparatus.

5.4. GRADING PROCESS

Table 1 demonstrates how the graded approach is applied across all phases of the ADDIE process. Examples provided within each phase show where opportunities to realize efficiencies could be achieved by selecting the appropriate grade at which to implement SAT.

Grade the SAT level to be applied against the following criteria:

- Its relative importance to safety, safeguards and security;
- The magnitude of any hazard involved;
- The life cycle stage of the facility;
- The mission of the facility;
- The particular characteristics of the facility;
- Other relevant factors.

Once the overall grade for the implementation of SAT is set this can be further graded within each phase of ADDIE where appropriate, the grade of SAT being applied should be kept under continuous review during all ADDIE stages to ensure the right level is being utilized.

For example, the position of a Reactor Operator would naturally fall within a Grade 1 implementation of SAT, however during the analysis phase it may be more efficient to conduct a gap analysis against a similar position at another facility rather than initiating a full job task analysis. Similarly, during the design and development phases KSAs (knowledge, skills and attitudes) and training material for a similar position may be available against which a gap analysis could be conducted. In these cases, the initial grade 1 implementation of SAT remains but efficiency adjustments can be made within each ADDIE phase by utilizing existing materials/analysis.

Table 1 provides some examples of activities and efficiency adjustments to consider when initially selecting or re-evaluating the grade at which to apply SAT.

TABLE 1. SAT GRADES

Steps of ADDIE	**Grade**	**Activity**	**Possible Efficiencies**
Analysis	Grade 1	Conduct detailed JTA/JCA (job and task analysis/job competency analysis) for all activities and tasks.	Do all elements or tasks fall under these criteria, or could a subset be identified as Grade 2? Does analysis exist for a similar position/task that could be reviewed?
Analysis	Grade 2	Conduct detailed JTA/JCA for specific activities and tasks.	Use of simple tabletop exercise to identify required KSAs. Gap analysis against existing analysis from a similar role/task. Recognition of pre-qualifying qualification or knowledge. Less frequent training committee review and approval.
Analysis	Grade 3	Conduct limited JCA where required.	In most cases a limited job/role/competency analysis based around a competency or SQEP register would be enough to determine the training needs.
Design	Grade 1	Conduct detailed design for all KSAs identified.	Do KSAs exist for a similar position/task that could be reviewed?
Design	Grade 2	Conduct detailed design for specific KSAs.	Utilize existing training design where possible, such as previously developed objectives and test questions. Consider the approval of learning objectives outside of normal training committee meetings.
Design	Grade 3	Conduct limited design activities only where required training is not already available.	Use existing training where available. No requirement to approve learning.
Develop	Grade 1	Conduct detailed development for all training material and resources required.	Does training material exist for a similar position/task that could be reviewed?

TABLE 1. SAT GRADES, cont.

<table>
<tr><td>Develop</td><td>Grade 2</td><td>Conduct detailed development for specific training material.</td><td>Utilize existing training material and resource where possible, such as previously developed lesson plans and resources.

Consider the approval of lesson plans outside of normal training committee meetings.</td></tr>
<tr><td>Develop</td><td>Grade 3</td><td>Conduct limited development activities only where required training is not already available.</td><td>Use existing training where available.

No requirement to approve lesson plans at a training committee.</td></tr>
<tr><td>Implement</td><td>Grade 1</td><td>All training delivered, assessed and recorded as designed.</td><td rowspan="2">Consider simple methods for collecting feedback post training – such as capture of instructor led discussion rather than reliance on standard feedback forms.

Consider recognition of prior knowledge or learning.

Consider remote delivery options to maximize attendance and minimize travel/time away from work.</td></tr>
<tr><td>Implement</td><td>Grade 2</td><td>All training delivered, assessed and recorded as designed.</td></tr>
<tr><td>Implement</td><td>Grade 3</td><td>All training delivered, assessed and recorded as designed.</td><td>No requirement to complete a training pilot event.

Consider the value that will be added before formally gathering and analyzing feedback following training.

No requirement to review training feedback at a training committee.

An SME rather than a qualified instructor may deliver training.

Formal evaluation (examination) may not be required.</td></tr>
<tr><td>Evaluate</td><td>Grade 1</td><td>Levels 1, 2, 3, and 4 training evaluation fully implemented.</td><td>Frequency of level 3 & 4 evaluation may be reduced for mature training programmes.</td></tr>
<tr><td>Evaluate</td><td>Grade 2</td><td>Levels 1, 2, 3, and 4 training evaluation implemented at appropriate level.</td><td>Frequency of level 3 & 4 evaluation may be reduced for mature training programmes.</td></tr>
</table>

TABLE 1. SAT GRADES, cont.

Evaluate	Grade 3	Formal training evaluation is not required.	Evaluation is conducted to ensure any identified business need or performance gap has been closed. No requirement to review training evaluation at a training committee.

The expanded flowchart (see Fig. 1) provides some additional factors to consider when initially selecting or re-evaluating the grade at which to apply SAT.

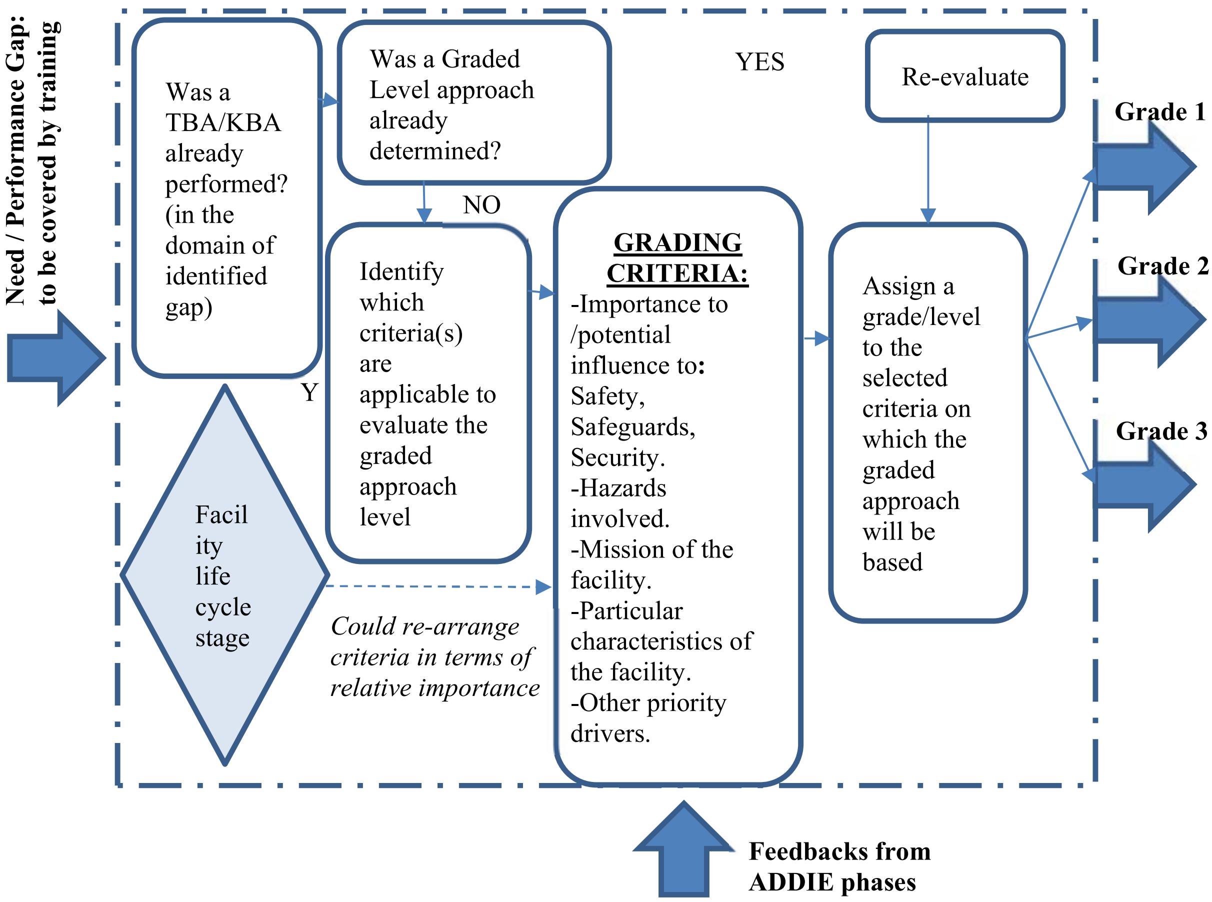

FIG. 1. Factors to consider grade at which to apply SAT.

6. CASE STUDIES

6.1. GRADED APPROACH AND EFFICIENCY IN SAT IN SPANISH NUCLEAR POWER PLANTS ALMARAZ, ASCÓ, AND VANDELLÒS II

6.1.1. Introduction

This case study has been developed by three Spanish nuclear power plants (NPPs): Almaraz, Ascó and Vandellòs II. A graded approach had already been implemented in those stations, based on experience with little or no guidance. The cornerstone of this grading process was developing a full SAT for Category 1 (licensed operators training programmes, non-licensed operators, maintenance electric, mechanic and Instrumentation & Control (I&C) maintenance, engineering, radiation protection (RP) and chemistry), while a competence analysis based on job functions was implemented for Category 2. Bureaucracy was basically the same for Category 1 and 2 workers, although it was simplified for Category 3. Further information is provided in Section 6.2.2.

This case study re-grades the different positions. This re-grading process will be performed considering all phases of SAT in this case study; the possible efficiencies identified for each phase will also be underlined.

6.1.2. Nature of the Considered Nuclear Facility

As mentioned above, this case study has been conducted by three Spanish NPPs: Almaraz, Ascó and Vandellòs II. Training programmes and procedures are common for Ascó and Vandellòs II facilities, and very similar to those of Almaraz. Line managers own their training programmes, while Plant Managers or Directors oversee the process through different levels of committees.

All three facilities implemented a similar graded approach to SAT in their training programmes. Those programmes are classified in three different categories:

— *Category 1:* Licensed operators training programmes, non-licensed operators, maintenance (electric, mechanic and I&C maintenance), engineering, RP and chemistry. A full SAT has been developed for each of those training programmes. This SAT is reviewed periodically every six years, although changes are implemented when required by training committees. The review committees meet periodically before each training session. Training process is overseen by directorate training committees and strategic training committees; both meet twice a year. Training indicators based on The Objectives and Criteria for Accreditation of Training in the Nuclear Power Industry, National Academy for Nuclear Training, INPO ACAD 02-001 rev. 1 [4] standard are measured quarterly.

— *Category 2:* Other safety-related staff, belong, among others, to departments such as QA, Training, Procurement or Work Management. Initial training programmes are based on competency or functional analysis (no JTA has been performed). Requirements for design, development and implementation phases are essentially the same as for Category 1 workers. However, continuing training programmes are based on training needs analysis performed by the training committees or equivalent meetings (there is no backbone schedule based on JTA). Key performance indicators (KPIs) only measure training attendance and training satisfaction (surveys to trainees or managers observations).

- *Category 3:* Non-safety related staff belonging to departments such as Human Resources, Accounting, etc.). A graded SAT analysis has been performed and a basic initial training is provided. If additional training needs are identified by managers or supervisors, training is usually outsourced to external vendors. There aren't any training committees or meetings and KPIs only measure training attendance and training satisfaction.

6.1.3. Motivations for a SAT Implementation (or Re-evaluation)

Spanish NPPs performed a SAT for licensed operators training programmes at the beginning of their operation (early 1980's). About 15 years ago the Spanish facilities asked the Institute of Nuclear Power Operations (INPO) to conduct a gap assessment and to evaluate the quality of those training programmes. Conclusions were extended to all Category 1 training programmes, including the deployment of a SAT. At the same time, the Spanish regulator published Instruction IS-12, where stations were told to develop a systematic approach (SAT, competence analysis or other approaches). This requirement was successfully covered through the aforementioned SAT.

To guarantee that the SAT remains updated, it undergoes a comprehensive review every six years.

6.1.4. Process/Case Study Description and Graded Approach

The process to be implemented by the Spanish NPP can be summarized as follows. The different steps are approved by the Strategic Training Committee before their effective implementation:

- Review if this graded approach is aligned with the Spanish regulation;
- Provide training on graded approach to line managers, training coordinators, training staff and instructors;
- Review of the current 3 Categories following the grading criteria described in chapter 5.2 of this TECDOC;
- Review (simplify) the JTA conducted for Grade 2 job positions. Non-safety-related tasks will be excluded from the JTA;
- Review both initial training programmes and the continuing backbone schedule for Grade 2 job positions, based on the reviewed JTA;
- Consider recognition of prior knowledge or learning for certain training courses;
- Promote remote learning (e-learning, streaming, newsletters, etc.) for some topics and for all 3 grades;
- Consider not requiring a formal trainee evaluation in certain topics for grade 3 trainees;
- Promote the implementation of training by subject matter experts (SMEs) with no support of a qualified instructor for certain topics for grade 3 trainees;
- Consider performing a global training effectiveness for Grade 1, training effectiveness measurements for selected topics for Grade 2, and no training effectiveness evaluation for Grade 3;
- Review the current KPIs since different indicators should be required for Grade 1, Grade 2 and especially Grade 3;
- Review the training procedures affected by the new approach.

In addition, training on SAT, graded approach and training needs analysis will be provided to people qualified as Operating Experience (OE) analysts to optimize the amount of training. The goal is to reduce the number of training hours that do not clearly originate from performance gaps caused by lack of knowledge and skills.

The main expected outcomes are:

- Grade 1 will (initially) include:
  - Licensed operators;
  - Field operators;
  - Chemistry operators (chemical analysts);
  - Mechanical, electrical and I&C operators;
- Grade 2 will include:
  - Engineering personnel;
  - Other maintenance staff;
  - Radiation protection staff;
  - Other chemistry staff;
  - Quality assurance staff;
  - Procurement engineering personnel;
  - Training personnel;
  - Work management staff;
  - Safety-related managers;
- Grade 3 will include the remainder of the staff.

Administrative procedures will be excluded from the JTA analysis in Grade 1 and Grade 2 staff, unless they have an impact on reactivity.

SAT will be reviewed for Grade 2 personnel, focusing on safety-related tasks. Other approaches (competence or functional analysis) will be considered to reduce the bureaucracy in tasks that do not affect reactivity. Guidelines for Training and Qualification of Engineering Personnel, National Academy for Nuclear Training, INPO ACAD 98-004 rev. 4 [5] will be taken as a reference for engineering personnel.

Training committees or equivalent meetings will be simplified for grade 2 and 3 personnel. Actions such as reducing the frequency of the meetings; and/or grouping all the current training committees in the departments like HR in one single committee will be implemented.

Recognition of prior knowledge will be included in the training procedures.

No statistics can be provided at this point. However, the abovementioned process will reduce both bureaucracy and number of training hours provided for non-critical workers.

6.1.5. Outcomes, Benefits and Lessons Learned

As already mentioned, this case study has not been implemented yet. However, it provides a guideline of actions to be taken following the flowchart in Annex I and develops some of the topics included in the Annex.

The main identified difficulties are:

- High workload to implement the changes;
- Possible non-compliance of certain parts of the process (especially for licensed operators) with Spanish regulation;
- Implementation of a change management process, including training or coaching of line managers and training coordinators.

On the other hand, expected outcomes are:

- Bureaucracy will be reduced (Grade 2 and 3);
- Training effort will focus on critical staff;
- Reduction of training hours for Grade 2 and 3 staff**.**

6.2. APPLICATION OF A GRADED APPROACH TO TRAINING FOR THE SPANISH NUCLEAR REGULATOR STAFF

6.2.1. Introduction

A systematic approach to training (SAT) is a proven and structured method for efficient qualification focusing on the performance of work, addressing the needs and deficiencies of the personnel and organizations. Training results contribute to improve work results and professional development of people.

In 2020, TECNATOM applied the SAT methodology to the staff training programme of the Spanish Nuclear Regulator (Consejo de Seguridad Nuclear, CSN), the sole nuclear safety and radiation protection authority in Spain. The CSN is governed by public law and by its charter. It is independent from the central government and possesses its own legal personality and assets. It is accountable to the National Congress of Deputies and to the National Senate.

The CSN's mission is to protect employees, people and the environment from the harmful effects of ionizing radiation. It accomplishes this by ensuring that nuclear and radioactive facilities are operated safely, and by establishing the preventive and corrective measures to be applied in all radiological emergencies, no matter their source.

The objective of the development of this project was to review the current CSN's training programmes under the application of the SAT methodology to guarantee that initial and continuous programmes are performance-based and do not have important gaps. Prior to the implementation and development of this project, CSN training programmes were developed based on the experience curricula of the professionals in the regulatory body. Also, it was taking into account training needs suggested either by employees or their supervisors.

6.2.2. Process/Case Study Description and Graded Approach

The scope of the project comprised the first two phases of the SAT methodology. which consist of:

1. Analysis: In this phase, the training needs are identified to meet the competency requirements associated to each job position;
2. Design: Training needs related to specific competences are converted into learning objectives, which are then organized in training plans, considering the available options and methods for training.

The general approach to obtain a classified list of competences was based on the competence model described in the International Atomic Energy Agency (IAEA) Safety Reports Series No.79 [6], which structures the required competences into four competence area.

As listed in Table 2 below, each of these competence areas comprises a set of specific competences referred to as knowledge, skills and attitudes (KSAs).

TABLE 2. REQUIRED COMPETENCES

Competence Area	Competence
Competences related to the legal, regulatory and organizational basis	• Legal basis • Regulatory policies and approaches • Regulations and regulatory guides • Management system
Technical disciplines competences	• Basic science and technology • Applied science and technology • Specialized science and technology
Competences related to a regulatory body's practices	• Review and assessment • Authorization • Inspection • Enforcement • Development of regulations and guides
Personal and behavioural competences	• Analytical thinking and problem solving • Personal effectiveness and self-management • Communication • Teamwork • Managerial and leadership competences • Safety culture

The competences are graded and grouped by the level of proficiency needed to properly perform the tasks as follows: 1 basic, 2 intermediate, 3 advanced.

As a first step, TECNATOM analyzed the procedures and documents applicable to obtain the relation of tasks associated to each job position at the organization (Task List).

Then, the Task List passed through the validation process by means of systematic discussions with the incumbents of each job position. Discussions were also held with the respective supervisors, as to validate their own tasks lists as well as the tasks lists of their collaborators. This approach allowed to take advantage of the vision of the supervisors to validate and to obtain well-constructed tasks lists. During the discussions with the supervisors, difficulty, importance, and frequency of each task (DIF) was established. The result of the DIF algorithm application determines the need for initial or continuous training for each task.

For each task selected as part of the training, a deep analysis was performed to extract the knowledge, skills, and competences associated to the tasks. In order to carry out this analysis in more depth, it was necessary to gather information about the tasks by consulting all procedures and documentation provided by the CSN. On some occasions it was also necessary to interview the job incumbents to identify what knowledge and skills are necessary to perform these tasks efficiently.

Competences were classified according to the model described in Ref. [6].

In relation to the competences the last competence area int the Table 2 that is, personal and behavioral competences, a different strategy was followed. To homogenize the result, one personal and behavioral competence was assigned to each group of job positions in the CSN. These competences were analyzed separately considering that these competences are inherently embedded in every task.

Once the necessary competences for each task selected for training were obtained, it was time to analyze them to define the learning objectives. The learning objectives were designed in accordance with the Bloom taxonomy to create well-constructed objectives that reflect the goals to the students.

The learning objectives were grouped to obtain the training courses and to organize them in suitable training programmes for each job position.

6.2.3. Results

All job positions at CSN were considered in the scope of the project, not only job positions belonging to the technical areas.

During the analysis phase, some former job positions were grouped after the analysis of procedures and documents concluded they shared common tasks. According to this, 84 job positions that grouped 188 specific job position were created.

Figure 2 shows an example of the grouping made after the Analysis phase of the project. The job position named 'Technical Coordinator' grouped four different technical coordinators. These technical coordinators have a set of common tasks and each of them has some specific tasks.

JOB POSITION	SPECIFIC JOB POSITION
TECHNICAL COORDINATOR	Operational radioprotection Coordinator
	Inspectors' Coordinator
	Nuclear facilities' Coordinator
	Emergencies Coordinator
	Public radioprotection Coordinator

FIG. 2. Example of grouping job positions.

For all analyzed job positions belonging to technical areas, around 500 competences were extracted. The analysis of these competences generated around 170 courses related to competency 1, 2 and 3.

For job positions belonging to non-technical areas, 250 competences were extracted, and 240 courses were designed.

Regarding the competences in quadrant 4, twenty-five (25) courses were designed.

6.2.4. Outcomes, Benefits and Lessons Learned

SAT methodology includes activities to accomplish the following:

— Identify if and what training should be provided for each position;

- Design and develop training programmes with explicit learning objectives and appropriate content;
- Conduct training as designed;
- Ensure that trainees master the learning objectives before they commence work in assigned positions;
- Evaluate training effectiveness and use these results to maintain and improve training.

The scope of the project included only the first two phases of the SAT methodology, and as a result, the training programmes for all existing job positions at the CSN were created. The next steps, prior to the training implementation, are to assess the training gaps that employees could have and to develop and conduct the training according to the established programmes.

Thanks to these designed training programmes, CSN staff acquires the necessary knowledge and skills to perform the tasks associated with their job in an efficient manner. People going through these training programmes feel they are empowered by the time they invested in training because they obtained the knowledge and skills needed to perform their work.

6.3. APPLICATION OF GRADED APPROACH IN OPERATOR'S SIMULATOR TRAINING IN TIAN WAN NPP, CHINA

6.3.1. Introduction

Training plays a crucial role in the management system of an NPP. However, from 2019 to the end of 2022, analysis of operational events in Chinese NPPs revealed a significant proportion of events caused by human errors. While there are clear requirements for operational risk identification and evaluation goals, there is a lack of standards for training and quantitative evaluation of operational events. Risky and complex operations, as well as relevant experience, have not been adequately addressed in training programmes. Furthermore, the absence of a graded training system results in duplicated content, waste of resources, and inefficient use of trainees' time. These shortcomings pose challenges to the effective training of personnel in a considered nuclear facility.

6.3.2. Motivations for a SAT Implementation (or Re-evaluation)

The training grading application for operator simulators is based on the following reasons.

6.3.3. Impact of Operation Risk on Nuclear Power Units

Operation events caused by operational risks constitute a significant portion of operational event statistics in nuclear power plants. The failure to effectively control operational risks has become a key factor leading to operational events in the nuclear power industry.

6.3.4. Training and Management Requirements

The World Association of Nuclear Operators (WANO) and Chinese nuclear power training level identification and evaluation objectives necessitate the identification of potential operational risks in NPP activities and comprehensive assessment of the potential impact of inadequate training on NPPs. However, there is a lack of established practices and specific standards for comprehensive risk management guidelines. Existing human error prevention tools in domestic nuclear power units focus solely on controlling operational risks during work processes and lack pre-emptive quantitative evaluation of training and classification of operational events.

Therefore, to address the current situation of operational risk control in NPPs and mitigate the potential for serious operational events, the establishment of a graded control system tailored to the training and operational events of nuclear power units is crucial. This approach not only fills the gap in the quantitative evaluation of operation risk-related training in domestic NPPs but also enables the graded control of analyzed operational events, thereby reducing the likelihood of operational events, transients, and other risks associated with operations.

6.3.5. Process / Case Study Description and Graded Approach

Specific measures for operational event training graded control are presented below.

6.3.6. Risk Identification of Operational Events Based on Nuclear Power Data

Risk identification is an essential step in implementing graded control training. It involves analyzing, evaluating, and classifying potential risks in operations based on factors such as the seriousness, possibility, and controllability of risk occurrences. This analysis incorporates A/B condition reports, experience feedback, and real NPP unit operation data (including 1,655 A/B condition reports) while considering the operational style of daily planned operation risk control management. Risk criteria are established based on three dimensions of risk factors.

6.3.6.1. Run event risk analysis and evaluation, and establishment of the "Run Event Risk Analysis Form" database

Qualitative analysis results are quantitatively assessed using numerical values. A comprehensive three-dimensional analysis and evaluation method is developed, taking into account the probability, severity, and controllability of operational event risks. This method combines general risk assessment principles with the specific characteristics of nuclear power plants. The analysis results are used to define the risk level using a risk volume-based formula (Formula 1). The establishment of a "Run Event Risk Analysis Form" database facilitates the storage and retrieval of risk analysis data.

Formula 1: Formula for training event priority quantification (Rv) calculation

$$Rv=P\cdot S\cdot C \tag{1}$$

Rv is the amount of training event priority; P is the possibility of risk occurrence; S is the seriousness of risk occurrence; C is the controllability of risk occurrence.

Low priority: $Rv<15$; medium priority: $15\leq Rv<36$; high priority: $Rv\geq 36$.; Scale: 0-5.

Based on the grading results, the frequency of training and the number of instructors can be determined. The training plan should be formulated considering the specific needs identified in the grading process. This includes determining the topics, content, duration, and delivery methods for each training session. The plan should also take into account the availability and expertise of instructors who can effectively deliver the training.

After the training is conducted, a tracking system should be implemented to monitor the recurrence frequency of operational events. This tracking helps assess the effectiveness of the training and identify any gaps or areas for improvement. By analyzing the recurrence of operational events, the training programme can be iteratively refined to achieve closed-loop control and continuous improvement in addressing operational risks.

6.3.6.2. *Develop and design tailored training courses for different levels of trainees*

In the process of operator retraining, the trainees include the shift supervisor, senior operator, operator, and the unauthorized operator, who possess varying levels of knowledge, skills, experience, and responsibilities. If there is no training grading and the same content is used, it may result in trainees at different levels not receiving the specific training courses they require. Therefore, multi-level training courses were developed, wherein the same training content is presented with different depths and priorities. This approach also serves as a form of training grading.

6.3.7. Outcomes, Benefits and Lessons Learned

The training graded approach emphasizes the training and management of operational events, establishes an effective feedback system for capturing experience, and strives to enhance the effectiveness of operator training. Its primary objective is to ensure that employees possess the necessary qualifications to effectively and efficiently maintain nuclear safety in accordance with established standards.

6.4. A CASE STUDY ON IMPLEMENTING A GRADED APPLICATION OF SAT IN NON-REACTOR NUCLEAR FUEL CYCLE FACILITIES

Disclaimer: This case study is intended to provide a general scenario in which the nuclear regulatory body of Country XYZ brings into effect a new regulatory framework mandating a risk informed, graded application of SAT in specific facilities that previously were exempt from using the SAT methodology. This case study represents a “real-life” example that was used by a Member State’s regulatory body to implement a SAT across nuclear facilities which previously did not have such requirements.

The author of this case study is Martin Vesely – Canadian Nuclear Safety Commission.

6.4.1. Introduction

Country XYZ has nuclear facilities that comprise the ‘closed’ fuel cycle, i.e., uranium mines, mills, refineries, conversion facilities, fuel fabrication, NPPs, research reactors, and waste facilities.

Traditionally, the SAT methodology was used in training systems and programmes for nuclear reactor personnel in areas such as management and leadership, operations, maintenance, engineering, technical support, radiation protection, chemistry, training, emergency preparedness & response, and general roles.

The country’s nuclear regulator has recently notified licensees that new legislation and associated regulatory framework will be brought into effect, which stipulates that a Systematic Approach to Training (SAT) will be required at non-reactor nuclear fuel cycle facilities, such as uranium conversion or fuel fabrication facilities. As stated in Ref. [1], “This graded approach needs to be based on consideration and weighing of the nuclear safety risks as a priority, in some circumstances followed by the commercial business risk to the facility”.

Furthermore, as per this document, the new requirement for SAT applies to positions at these facilities where a consequence of human error would cause impact on health and nuclear safety or environmental operations.

Licensees have been afforded a transition period in which to implement a SAT.

6.4.2. Nature of the Considered Nuclear Facilities

For the purposes of this case study, the facilities in question are a uranium conversion facility, and a fuel fabrication facility. Each licensee will need to present a case to the regulatory body, indicating which personnel has roles where the consequence of human error would cause an impact on nuclear, health and safety or environmental operations, resulting in the requirement for SAT-based training.

The licensees have no previous experience with SAT but have training programmes in place for personnel which contain elements of SAT such as continuing training and periodic evaluations.

6.4.3. Motivations for a SAT Implementation (or Re-evaluation)

The licensee implemented a SAT as a result of changes in the regulatory framework which now requires a SAT for personnel in positions where the consequence of human error would cause an impact on nuclear, health and safety or environmental operations.

6.4.4. Process/Case Study Description and Graded Approach

As the regulatory framework has changed other fuel cycle facilities are now required to implement SAT for personnel in positions where the consequence of human error may cause impact on nuclear, health and safety or environmental operations.

6.4.4.1. General process to be followed by the Regulatory Body

- Promotional activities: Prior to the regulatory framework being formally amended, the regulatory body staff should undertake promotional activities such as in person meetings, baseline benchmarking inspections and presentations, in order to advise, assess the current training programmes, and educate licensee staff of the forthcoming changes and expectations;
- Provide initial guidance to licensees via this document or to draft and disseminate for industry comments, its own regulatory document documenting requirements and guidance regarding SAT application;
- Given the general findings from step one and two above, determine a transitional period for licensees in which licensee personnel can complete and validate the steps to be undertaken below (General process to be followed by licensees);
- Formally document the new requirements and disseminate the requirements and guidance to the applicable licensees;
- Formally incorporate licensees training system governance documentation (from Steps 3,4 and 5 below) into the regulatory framework for licensing and compliance purposes.
- Conduct compliance inspections.

6.4.4.2. General process to be followed by licensees

Formally conduct organizational analysis to determine which positions meet the definition of personnel in positions where the consequence of human error may cause impact on nuclear, health and safety or environmental operations. Assign a Grade to the identified positions as per this document, Section 5.2 “Grading Criteria” following the below steps:

- Document the proposed personnel positions and submit them to the regulatory body for evaluation and acceptance;
- Regulatory body formally agrees or adapt the submitted list of personnel positions and grades assigned as per this document, Section 5.2 “Grading Criteria”;
- Licensee determines the SAT system that will apply and publishes corresponding governance which will describe in detail the SAT and its phases (analysis, design, development, implementation, and evaluation) to be used, e.g., given the personnel positions identified, priority for SAT implementation will be given to highest risk positions; a job and task analysis will be conducted via table-top exercise with personnel occupying the position, the training manager, staff and representation from senior management;
- Licensee submits the SAT governance to the regulatory body for acceptance;
- Regulatory body formally either accepts or requests that the licensee amend the governance;
- Licensee commences a JTA on the highest risk positions to determine the tasks that will require no training, initial, or initial and continuing training since not all personnel positions are likely to be brought into compliance with the agreed SAT governance at once;
- Complete remainder of SAT phases in accordance with approved governance starting with highest risk position;
- Implement training programme starting with highest risk position as per governance;
- Regulatory body should formally communicate and accept any changes as the SAT based training system, governance documentation, and training programmes are now considered part of the regulatory framework for licensing and compliance;
- Coordinate with regulatory body facilitation of compliance inspections of implemented SAT based training system.

6.4.5. Outcomes, Benefits and Lessons Learned

By following the above process, the licensees enter into a constructive dialogue with the regulator and are empowered to tailor a SAT system and accompanying training programmes addressing their own operational needs as well as meeting regulatory requirements. By addressing the highest risk positions first, the licensees are provided with a risk-informed “path forward” for the implementation of SAT.

The lessons learned are documented in the recommended processes to be followed in Section 5 of this document.

This case study emphasizes the importance of using promotional activities directed towards licensees.

The IAEA document [1] and this document, provide a basis, from which the regulatory body can choose to adopt or adapt the guidance provided. The agreed regulatory requirements and guidance are then to be disseminated to the applicable licensees. Consultation and benchmarking inspections play an important role in ensuring successful and timely implementation of a SAT which meets regulatory requirements.

As stated in Ref. [1] “The choice to use SAT is founded on the ability to identify the specific tasks and activities that can impact nuclear safety, specifically those tasks and activities that, if not conducted correctly, will have a direct impact on nuclear safety and reactivity controls.”

6.5. GRADED APPROACH TO TRAINING: RECOGNIZING THE CRITICALITY OF ROLES TO MAKE A TRAINING PLAN EFFECTIVE AT THE NATIONAL ATOMIC ENERGY COMMISSION, ARGENTINA

6.5.1. Introduction

People are the main protagonists of an organization as they contribute to the production of knowledge and offer creative and innovative solutions. They are involved in research activities aligned with the institution's mission. In order to actively participate in development projects, professionals require specific training. SAT is the primary tool used for this purpose. To facilitate this process at the National Atomic Energy Commission (CNEA) of Argentina, training is provided to all staff members. The training is designed to address common and urgent problems, and it offers theoretical foundations and tools in scientific and technological areas of specialization.

Within this context, there is a need to expand specific training programmes to achieve objectives that encompass various areas of CNEA and require collaboration among different groups. Following the SAT procedure developed for nuclear companies, the training begins with the identification and analysis of needs. This analysis informs the development of content programmes, followed by the implementation of instructional methods and the evaluation of training objectives.

We believe that the analysis phase of the SAT process can be enhanced by including a survey to identify and focus on critical roles. Conducting this survey can yield several benefits, including:

- Identifying positions that pose higher risks to the achievement of strategic plans;
- Highlighting critical areas based on required skills and determining the relevant training topics for each specialized area, both presently and in the future;
- Determining perceptions and the degree of acceptance of training initiatives.

This work proposes a role-based procedure for evaluating the SAT by identifying and prioritizing critical roles. The evaluation involves assessing the existing roles and defining the risks associated with them based on the information they handle. This evaluation is conducted from top to bottom within the organization to provide a comprehensive overview of the complexity levels of work and tasks, as well as a map of the organizational structure and positions. This information is essential for defining competency requirements and identifying knowledge gaps to effectively plan the training programme.

CNEA, the national nuclear research and development organization in Argentina, operates multiple facilities across the country, including three main atomic centres. One of these centers is located in the city of Bariloche. Throughout its history, CNEA has been known for its commitment to developing innovative knowledge and providing training to its personnel. This dedication is a fundamental aspect of the organization's existence.

CNEA offers career opportunities to young professionals and provides specific courses through its prestigious academic institutes: Balseiro, Sabato, and Beninson. These institutes support the continuous training of CNEA staff, ensuring they stay equipped for their roles.

Given the scale of ongoing projects within the institution, it is crucial to regularly align the strategic plan with training activities. Therefore, it is proposed to conduct a comprehensive training needs assessment. This assessment aims to redefine development objectives and serve as the foundation for designing specific training programmes for CNEA personnel. These programmes can be conducted within the CNEA Institutes, the respective departments, or through collaborations with external institutions.

6.5.2. Process to Evaluate the Role

Assessing the level of a role involves determining the complexity of the information it handles and evaluating the associated risk. As work systems ascend, roles engage in tasks of increasing complexity, requiring more time to be completed.

To categorize critical layers within the organizational structure, the premise was established that critical layers necessitate greater seniority due to the complexity of handled information. This premise is particularly applicable when there is no designated group of successors for managerial positions.

It is proposed to work with three main strata: stratum IV, stratum III, and stratum II, drawing from the works of Dr. Elliott Jaques and Dr. Aldo Schlemenson, who present a managerial model for organizational design.

Within each level, typical positions are defined as follows: 'Director' for stratum IV, 'Manager' for stratum III, and 'Team Leader', 'Coordinator', 'Researcher', and 'Analyst' for stratum II.

Here is a brief description of the complexity associated with each level and its respective roles:

- Director: This level encompasses functional directors, area managers within CNEA, or project managers overseeing three or more managers. The complexity at this level involves handling multiple long-term interactive projects (ranging from 2 to 5 years) concurrently, while ensuring their alignment and harmonization. Tasks at this level entail strategic technological or organizational changes, such as product innovation, problem analysis leading to original solutions, addressing a declining market situation, developing international markets, and creating new business units based on strengths and opportunities;
- Manager: This level entails leading a broad and dispersed group of individuals and departments. The manager oversees at least three subordinates who should be managed in a coordinated manner to achieve desired outcomes within the area. The role requires an understanding of processes and their interrelationships, along with the ability to anticipate their impact on subsequent stages. The responsibilities include planning, spearheading new developments, product innovation, managing operational projects, and monitoring trends with a timeframe of 1 to 2 years;
- Head or Team Leader: This level represents the initial tiers of leadership. The role involves leading and managing groups of employees and departments. The head or team leader is accountable for the performance of their team, from which they obtain their results. Within CNEA, this level encompasses department heads and division heads overseeing multiple groups;
- Researcher or Coordinator or Senior Analyst: These positions encompass specialists who possess expertise in specific areas of knowledge within each department. They are responsible for managing projects or cases involving 2 or 3 collaborators, with a duration ranging from 3 months to 1 year. Their work involves gathering and evaluating significant information, coordinating employees and departments, and ensuring the successful completion of the assigned tasks.

Each stratum is further divided into three distinct levels: high, intermediate, and low. These levels represent increasing work complexity and information handling. Directors are responsible for conducting the assessment and placing each role within the high, intermediate, or low level of their respective stratum, based on the perceived risk associated with each function. The final responsibility for the evaluation rests with positions higher than Directors, who review the results and provide guidance on aligning relative positions and criteria to ensure a fair and equitable analysis.

Table 3 shows a template of an assessment of roles at risk, to be used within this proposal.

Table 3. ASSESSMENT OF ROLES AT RISK TEMPLATE

Complexity of Roles		Role Risk	Role, Function, or Subject Area	SAT Grade of Role
Stratum	Role	Level		
IV	Director	High		Grade 1
		Intermediate		Grade 2
		Low		Grade 3
III	Manager Senior Researcher	High		Grade 1
		Intermediate		Grade 2
		Low		Grade 3
II	Team Leader Coordinator Researcher Analyst	High		Grade 1
		Intermediate		Grade 2
		Low		Grade 3

The premise underlying the assessment is that critical layers within the organizational structure demand greater seniority due to the increasing complexities of the problems and information handled in each role. This premise is particularly applicable in organizations lacking a designated group of successors for managerial positions. However, if there is an excessive proliferation of leadership positions within the structure, a revision of the approach is warranted.

Furthermore, it is beneficial to characterize the profiles associated with each level to facilitate the risk analysis of the roles. These profiles provide additional information that aids in assessing the suitability and potential risks associated with each position.

6.5.3. Application of SAT

Once the critical positions are identified, the implementation of the Systematic Approach to Training (SAT) are graded based on the complexity categorization of the roles. Positions placed in the upper level of a stratum are assigned Grade 1 in each phase of the ADDIE model. Roles in the middle band correspond to Grade 2, while lower-risk positions are considered Grade 3.

The following actions are to be taken:

- Elaborate detailed JTA/Job Competency Analysis for Grade 1 roles. This analysis encompasses all specialties, although a selection of roles may be necessary if the number exceeds a reasonable limit. As a general principle, the basic competencies of Grade 2 and 3 positions within a stratum are determined in comparison with Grade 1 roles;

- Produce a training diagnostic report that includes the areas of knowledge to be developed for Grade 1, 2, and 3 positions or functions. The report prioritizes training needs, suggests delivery methods, and outlines the expected outcomes;
- Adjust the training organization by defining interdisciplinary units responsible for implementing innovative and relevant training programmes. These units will undertake the complete ADDIE cycle, including defining general objectives, designing and developing course content and methods, selecting instructors, delivering training, and evaluating effectiveness. A training committee will oversee these units, ensuring the availability of resources and the achievement of desired results;
- Establish specific short and medium-term objectives for Grade 2 positions. These objectives will be operationalized through semi-annual or annual continuous training programmes. Activities in these programmes may include initial training courses at CNEA Institutes, obtaining certifications or licenses, participation in improvement groups, supervised work in specific areas, subject matter expert support, and collaboration with other departments;
- Determine specific objectives and training actions for Grade 3 roles. These actions will aim to fulfil the professional needs of employees and may include attending courses at external institutions, access to self-administered lessons, and utilization of online resources.

The responsibility for the training programmes lies with the training experts, while line managers review and approve the activities. All courses include evaluations and collect feedback from attendees after the completion of the activities.

6.5.4. Outcomes, Benefits, and Lessons Learned

Based on the analysis of the collected information, this work provides the following:

- A scale of reference positions that outlines the levels of managerial complexity within the organization. This scale identifies the areas and functions that are of greater criticality, helping to establish a framework for understanding the organizational structure;
- The basic competencies required for each critical area and level within the organization. These competencies serve as a guide for evaluating the skills and knowledge needed for different roles;
- A training diagnosis report that reflects the identified needs of the main areas within the organization. The report categorizes these needs based on the evaluation of each role's complexity. This analysis helps to prioritize training actions and align them with the strategic objectives of the organization.

Identifying position risks is crucial for identifying knowledge gaps and implementing focused training actions that support strategic objectives. A progressive top-to-bottom implementation of training fosters commitment and facilitates the transfer of knowledge to daily work, enhancing the effectiveness of the initiatives.

6.6. A CASE STUDY ON GRADING SAT TO IMPROVE TRAINING PROGRAMMES ON RISK IDENTIFICATION AND PREVENTION AT QINSHAN NPP, CHINA

QINSHAN NPP uses different posts and different levels SAT to improve training programme on risk identification and prevention.

6.6.1. Introduction

In 2022, an incident occurred at a nuclear power plant where a worker received a higher than planned exposure dose. The incident happened while the worker was removing an extension tool to replace a pressure tube during an outage. Unexpectedly, part of the pressure tube was brought out by the tool, triggering an alarm on the radiation monitor and indicating the worker's unplanned exposure dose.

Analysis of the incident revealed several root causes. Firstly, the maintenance procedures for this task were too general and lacked sufficient detail to provide accurate instructions to the workers. Then, the ALARA ("as low as reasonably achievable") plan failed to identify the risk of accidentally bringing the pressure tube out and did not have targeted preventive measures in place. Finally, the worker in this role and the manager lacked awareness and methods for identifying and preventing or control risks effectively.

6.6.2. Nature of the Considered Nuclear Facility

The nuclear power plant (NPP) operates nine power units, and its comprehensive training programme encompasses all positions. Following the incident, the training committee identified weaknesses in the existing on-the-job training programmes, specifically in the areas of risk prevention and control. The committee directed the training management department to conduct an analysis of positions related to major risks, ensuring that the training programme is reviewed, confirmed, and enhanced accordingly.

Furthermore, the committee emphasized the need to improve managers' understanding of risk control through targeted training. It was suggested that managers should be equipped with effective methods for identifying and controlling risks when proofreading, reviewing, and approving working documents. This initiative aims to enhance the quality of NPP regulations and procedure documents and ultimately contribute to overall improvement in risk management within the organization.

6.6.3. Motivations for a SAT Implementation (or Re-evaluation)

Following the training committee's general requirements, the training management department conducted a review of the existing on-the-job training programme system. The review identified that posts related to major risks were primarily concentrated in the fields of operation, maintenance, technology, safety, quality, and business. Additionally, it was noted that different departments and posts had varying training requirements for risk identification and control. To address these findings, the responsible individuals for training programmes, along with technical experts in the relevant fields, will conduct targeted analyses of their respective training programmes in terms of risk identification and control. This analysis aims to confirm the effectiveness of the programmes and identify any necessary corrective actions to enhance training outcomes.

Furthermore, during the review, it was observed that the NPP lacked training tasks and courses specifically addressing risk identification and control measures for managers in proofreading, reviewing, and approving working documents. As a result, there is a need to develop unified risk control courses, provide supplementary training, and improve the training programmes for managers according to the management requirements of the NPP.

6.6.4. Process/Case Study Description and Graded Approach

The training management department takes the following steps to address the identified needs:

- *Set up a special course development team:* A team led by the safety leader, including experts in risk management from the comprehensive risk management department (operations planning branch), is established. This team collects and analyzes the training needs of front-line managers;
- *Develop the programme course "Risk Identification and Control" for managers:* The course focuses on objectives such as identifying traps in risk control, applying risk identification methods to identify potential risks in tasks, understanding and applying SMART principles for preventive measures, and applying systematic risk prevention strategies;
- *Conduct a trial lecture and make revisions:* The developed courses undergo a trial lecture, and necessary revisions are made based on feedback. Once the courses are finalized, training sessions for relevant managers are conducted promptly.

Simultaneously, the training management department organizes special analysis, confirmation, and optimization actions for on-the-job training programmes in various fields (e.g., operation, maintenance, technology, safety, quality, and business). Each field's responsible personnel, along with training engineers and technical experts, form a dedicated team. This team conducts specific analysis and review of training tasks, objectives, and courses related to major risks in their respective fields. Defects in existing on-the-job training programmes are identified, and targeted supplements and improvements are made.

In these cases, different positions would apply different levels of the Systematic Approach to Training (SAT):

- - Safety-related departments: Grade 2. During the analysis phase, there is no need to reanalyze job tasks. Instead, the existing position analysis results are compared to identify performance gaps. In the design and development stage, the training objectives and materials are upgraded based on the identified gaps;
- - Non-safety-related departments: Grade 3. There is no need to conduct analysis or design new materials. Instead, the training materials developed by safety-related departments are adapted, revised, and supplemented for their specific needs.

6.6.5. Outcomes, Benefits and Lessons Learned

After almost six months of dedicated efforts, the NPP successfully developed the programme course "Risk Identification and Control" and conducted multiple rounds of training. Over 700-line managers and individuals responsible for training programmes received training and passed the examination.

Simultaneously, the on-the-job training programmes in the fields of operation, maintenance, technology, safety and quality, and business underwent thorough review and analysis. A total of 126 programmes were specifically revised by incorporating risk-related work tasks and training objectives. Additionally, 31 targeted programme courses were developed or revised, with training content tailored to address risk-related work tasks and objectives.

All these actions were executed in alignment with the systematic approach to training (SAT), ensuring that different positions underwent analysis and improvement at varying levels of SAT. The goal was to achieve targeted enhancements within the training programme system. The

NPP remains committed to employing SAT consistently and continuously to enhance the training programme system. It upholds comprehensive and standardized personnel training and authorization practices to ensure that staff in every position possess the necessary competence.

6.7. A CASE STUDY ON ENHANCING COMPETENCY-BASED APPROACHES FOR NUCLEAR INSPECTOR CERTIFICATION PROGRAMMES AT THE KOREA INSTITUTE OF NUCLEAR SAFETY

6.7.1. Introduction

Around the world, nuclear safety regulatory bodies issue nuclear inspector certificates to qualified personnel who perform regulatory duties. Once these certificates are issued, regulatory bodies provide follow-up training programmes for inspectors to maintain and enhance their skills and knowledge, ensuring their ongoing qualification. In the Republic of Korea, the Korea Institute of Nuclear Safety (KINS) establishes arrangements for the management and training of regulatory inspectors. KINS supports work related to nuclear or radiation utilization facilities, manages inspector qualifications, and issues certificates to individuals with specific competency qualifications.

For a considerable period of time, KINS has developed and implemented nuclear inspector certification programmes to qualify regulatory inspectors. Furthermore, to enhance the competencies of regulatory personnel and provide a new competency-based training programme that is more relevant, KINS has reviewed various approaches for developing training courses instead of relying solely on traditional methods such as the SAT (e.g., DACUM - developing a curriculum process, tabletop exercises, etc.). Based on this analysis, KINS has been searching for an SAT alternative to develop and improve the training course for nuclear inspectors.

6.7.2. Nature of the Considered Nuclear Facility

As of December 2022, the Republic of Korea has a total of 25 nuclear reactors situated at four nuclear power plant sites nationwide. Furthermore, there are three units currently under construction, while two units have been shut down (source: opis.kins.re.kr/opis). In addition to these nuclear power plants, the country also houses various radiation-based facilities, including industrial radiation facilities, medical radiation facilities, and nuclear fuel fabrication facilities.

6.7.3. Motivations for the SAT Implementation (or Re-evaluation)

To enhance the effectiveness of current inspector training programmes and design a new training programme, KINS conducted a thorough review of different approaches for developing training courses. Among the various options considered, KINS decided to adopt a graded approach to SAT, which offers economic benefits and time savings compared to the traditional SAT methods.

In addition to the SAT, various alternative approaches for developing inspector training courses were explored. These included the DACUM process, tabletop exercises (as recommended by the U.S. Department of Energy), and verification methods. Case studies from other countries that employed the SAT for training programme development, such as Canada and Finland, were also examined. Notably, these countries utilized the SAT in designing training programmes based on job analysis.

Considering the findings from the analyses and trend studies, KINS determined that applying a graded approach to the SAT would be most suitable for conducting job/task competency analysis and developing regulatory inspector training programmes.

6.7.3.1. Process/Case Study Description and Graded Approach

Regarding the implementation of the graded approach to the SAT in inspector training programmes and qualification management, the following situations were observed:

The application of the graded approach involved the reduction or omission of the ADDIE (see below for the definition) phases of the traditional SAT. Specifically, existing materials and processes from the training programmes in each phase were utilized to facilitate a simplified graded approach to the SAT:

- Government decrees have specified and made public the management of nuclear inspector qualifications, including acquisition, maintenance, and the required training hours and fields.
- Existing operational training programmes for nuclear inspectors were already in place prior to the implementation of the graded approach to the SAT.
- Before adopting the graded approach to the SAT, the development of new training programmes and the supplementation of certain aspects of existing programmes were necessary. These adjustments were identified through reviews. It is important to note that KINS did not conduct grading for the training programmes related to nuclear inspectors, as it was not required according to the specifications outlined in the decrees.

In the context of the graded approach to the SAT, a significant amount of time was dedicated to the analysis phase among the five phases of the SAT model (Analysis, Design, Development, Implementation, and Evaluation). During this phase, a gap analysis was conducted to assess the competency and training requirements of nuclear inspectors in advanced countries. Internal experts from KINS were utilized to derive the necessary competencies for nuclear inspectors. Existing internal materials were also utilized to optimize the efficiency and effectiveness of the analysis phase, particularly concerning training hours, methods, and fields.

The analysis phase yielded numerous essential competencies, identified areas for improvement in existing inspector training programmes, and facilitated the development of new training programmes. The design phase, following the graded approach to the SAT, was streamlined as the government's decrees already specified the conditions for acquiring and maintaining qualifications as a nuclear inspector, including regulations on training hours, fields, and methods.

During the development phase, curricula and materials for training courses were prepared. The current regulatory inspector training programmes are divided into four certification areas, ranging from 5 to 16 hours in duration. However, it was decided not to implement this phase in the same manner as existing procedures for inspector training.

The implementation phase consisted of two stages: course preparation and conduct of training. In the course preparation stage, programme organizers obtained authorization, notified participants, and ensured the readiness of training rooms and equipment. During the conduct stage, KINS provided support and monitoring during the delivery of lectures. This phase followed a similar approach to existing training programmes, with adjustments made to newly developed courses and areas requiring improvement.

The evaluation and feedback phase involved the use of paper-based testing (PBT), with attendees needing to score above the threshold (above 60% of the total score) to officially complete the course. To gather feedback for course improvement, KINS conducted a satisfaction survey and collected written opinions. As part of the graded approach, the introduction of computer-based testing (CBT) and online surveys were considered during this phase and later implemented. Other methods and materials used in existing training courses were also incorporated into this phase.

6.7.4. Outcomes, Benefits, and Lessons Learned

The implementation of the graded approach to the SAT resulted in the identification of key competency elements and 161 specific competencies required for regulatory bodies. This led to the development of an improvement plan for KINS training programmes and the introduction of new training programmes. The process also revealed areas for improvement in government decrees related to nuclear inspectors.

In the face of rapid technological advancements, the graded approach to the SAT proved to be a suitable method for revising and updating existing training programmes efficiently. It addressed the limitations of the traditional SAT and resulted in significant time and cost savings. KINS gained valuable experience from adopting the graded approach, which effectively tackled challenges in programme management. By conducting a gap analysis of regulatory inspector training systems across different countries, KINS achieved desired outcomes by leveraging the benefits of the graded approach to the SAT. This tailored approach allowed for the allocation of fewer resources, reduced time commitments, and cost savings compared to the initial establishment of nuclear inspector training programmes.

6.8. APPLICATION OF A GRADED APPROACH FOR A COMPUTERIZED BASED TRAINING (CBT) PROGRAMME FOR BWR SEVERE ACCIDENT MANAGEMENT GUIDELINES (SAMG)

6.8.1. Introduction

The case study covered in this section is a BWROG (Boiling Water Reactor Owner Group) project called Severe Accident Interactive Learning (SAIL). The project consisted of the analysis, design, development, implementation, and evaluation of a Computerized Based Training (CBT) programme for BWR Severe Accident Management Guidelines (SAMG).

The Project Team is comprised of a set of nuclear industry representatives with varying degrees of expertise in Emergency Operating Procedures (EOPs), SAMGs, and the Systematic Approach to Training (SAT) process. Some of the organizations involved and their role within the project are listed as follows:

- BWROG Emergency Procedure Committee (EPC) - Technical data, reviews, interface with plants, overall responsible for CBT content.
- GEH (General Electric Hitachi) - Sourcing administration, technical data, and oversight support.
- Accelerant Solutions - Interface with the BWROG, Project Management, SAT deliverables and electronic interface for CBT software platform integration.
- Tecnatom - training production management, content development and interface with NANTeL which is the INPO Learning Management System (LMS).
- INPO - NANTeL host interface, SAT process guidance, software testing support, module certifications.

- US Department of Energy (DOE) and Electric Power Research Institute (EPRI) data source for severe accident modeling and phenomenology.
- Individual US BWR Nuclear Utilities Operations, Technical and Emergency Response Organization (ERO) Training - Final position qualification.

The purpose of the training programme is to equip the ERO staff with the knowledge to mitigate a severe accident. Based on the SAT process and role definitions in NEI 91-04, “Severe Accident Issue Closure Guidelines”, training was developed for the following positions of the ERO: SAMG Decision Makers, SAMG Evaluators, Licensed SAMG Implementers and Non-Licensed SAMG Implementers.

6.8.2. Nature of the Considered Nuclear Facility

This project was developed by the BWROG Emergency Procedures Committee for the entire BWR fleet.

This generic fleet training programme provides ERO Decision Makers, Evaluators and Implementers with sufficient knowledge in order to cool core debris, protect containment structures and to minimize radiological releases to the public in a Severe Accident.

The CBTs have been hosted on INPO´s LMS (NANTeL) and are implemented by the utilities remotely. The CBT is also hosted on the BWROG´s LMS for non-NANTeL BWROG Members.

6.8.3. Motivations for a SAT Implementation (or Re-evaluation)

Post-Fukushima reviews of severe accident training found inconsistent training from one power plant to another. Fukushima data was used extensively to develop the new revision of the BWR Owners’ Group EPG/SAG (Revision 4), “Emergency Procedure and Severe Accident Guidelines, issued to the commercial nuclear power industry in June 2018. Subsequently, the BWROG considered a need to consistently train nuclear plant personnel on these new SAMGs. This project was launched to create a new CBT programme for BWR SAMGs.

Standards and processes described in INPO NISP-TR-01, “Systematic Approach to Training Process”, have been followed for this project. The SAT based processes were applied to BWR severe accidents that progress to various stages, are predicted as mechanistically possible, or to which the BWR Owners’ Group EPG/SAG provides guidance to mitigate. Severe accident guidance has limited real world experience. Fukushima Daiichi events that took place following the historical earthquakes and tsunami that struck Japan on March 11th, 2011, provided significant data for severe accident study in the BWR Fleet. Industry evaluation of severe accident progression, mitigation and phenomenology are representative sources of accident system states and parameter interactions.

6.8.4. Process/Case Study Description & Graded Approach

A graded approach to the SAT process was used due to many unique factors regarding severe accidents including the breadth of topics covered, the breadth of individuals requiring the training, the inability to observe a plant response and the evaluative nature of the bases of the training content. For instance, Subject Matter Expert (SME) input, tabletop demonstrations, nuclear accident case studies and document reviews have been used for analyzing training tasks, task elements and job functions.

As the different roles involved in the ERO organization have different tasks, a different certification or learning path was created for each role. For instance, non-licensed operators receive only a portion of the full training compared to licensed operators. Therefore, excessive training and costs were avoided.

The project resulted in technical training of the new guidelines released to meet needs associated with providing consistent, maintainable, efficient and state of the art interactive computer-based training.

Remote learning provides benefits as follows:

- Training content consistency throughout the BWR Fleet;
- Training material accessibility for utility personnel with designed flexibility for obtaining and understanding the material;
- Training material maintainability for future needed or desired changes;
- Shared industry resources to produce quality and timely content;
- Shared industry resources to utilize existing software platform (NANTeL).

A graded approach on the Analysis phase was applied. After the Job and Needs analysis, a unique common task list for the above-mentioned four job positions was developed for the severe accident management Training Programme. The task list was extracted from the latest set of guidelines. This unified task list was used for a Difficulty Importance Frequency (DIF) assessment. This solution was determined as the most practical since the assessment of the job independent pieces of work would have taken the analysis to an unnecessary level of detail. The people who performed the DIF assessment were made up of a diverse group of positions or experience incumbents and SMEs.

The average DIF scores of the different participants were used for the application of the INPO sanctioned SAT algorithm and consequently, to assist in making the training determination:

- Non-trainable Task / Initial Training Task / Initial & Continuing Training Task
- Retraining frequency for Continuing Training Tasks

Finally, the Task-to-Training Matrix was output as the final deliverable of the Training Analysis phase. This matrix contains the bases for the design phase of the training programme.

At the completion of the Analysis Phase, the following processes were completed for the design stage:

- Determination of training setting;
- Definition of learning objectives;
- Sequence and organization of learning objectives;
- Creation of evaluation items;
- Training programme design;
- Job Certification Sequences.

The purpose of the training programme is to develop the technical knowledge and competencies required for the different severe accident management positions. This ultimate goal set the main basis for the training design.

Other aspects considered for the definition of the training programme were the containment design. Differences in containment design impact on the tasks associated to protect the containments, and to cool core debris. Based on these differences, certifications paths were developed for 1) Mark I&II, and 2) Mark III.

A set of learning objectives was created so that all the tasks defined during the analysis stage were covered by relevant training elements.

Learning objectives were organized into training modules. The objectives were mainly grouped by subjects or topics, but also considered the applicability to the different job profiles so that every profile receives training as required for the performance of their functions.

Lastly, content related to the tasks graded the highest during the DIF survey were verified to be selected for the continuing training content and emphasis. EPRI using a Machine Learning Artificial Intelligence process validated the importance of many tasks, such as core debris coolant injection and containment venting.

During the design stage, the objectives to be evaluated during the training implementation were correlated with a set of questions and maintained in objective based questions banks.

The last stage consisted of organizing the different modules into the certifications available in the SAMG training programme. Based on roles and containment design, several certifications were designed.

Development phase was initiated based on the training objectives, modules and certifications groupings approved at the conclusion of the design phase. The main steps of the development stage were the following:

- Development of New Training Material: A wide variety of educational resources were used in order to make the training materials as engaging and effective as possible. This media included, among others, figures, videos or animations. A development checklist was created to ensure the consistency in the development of the modules. The modules were developed using the commercial software Storyline by Articulate and PLANT™ (Tecnatom e-learning authoring tool);
- Review of Training Material. Several review stages were done by the development team (Accelerant and Tecnatom), and the BWROG team;
- Training Materials IT Testing. Considering the technological nature of the training materials, and the IT challenges involved in having different users from different utilities accessing the training from multiple locations, a testing programme was defined for the different modules;
- Approved Training Materials and approved modules were archived and locked down for future access. Training modules were made available for the Utility use through NANTeL and made Ready for Training.

The BWROG SAMG CBT was released for US Utility use in September 2020. The implementation phase is ongoing by BWROG, NANTeL, Utilities and trainees enrolling in and taking the CBT modules along with Utility specified Qualification requirements.

In 2021 and 2022 a maintenance project was undertaken in order to evaluate the available data, including student feedback, to improve the CBT. This is part of the final stage of a SAT process, Evaluation of the Training. A subsequent maintenance process resulted in an update and revision of the Training which was targeted for release in early 2023.

6.8.5. Outcomes, Benefits and Lessons Learned

This training programme has been mentioned by the US DOE as one of the key contributors to increase the performance and safety of BWRs in the U.S. after the Fukushima accident.

This training frees the utilities from having to develop and deliver their own training. It has been used by the BWR utilities to certify more than 3,000 individuals leading to important cost savings by reducing training cost by more than US $6 million per year in the BWR fleet *[ref: https://www.energy.gov/ne/articles/3-ways-fukushima-helping-enhance-nuclear-reactor-safety]*.

Also, the SAIL project was awarded with the 'BWROG Cost Saving Award' for the biggest cost saving in the US BWR fleet.

7. SUMMARY AND CONCLUSIONS

There are many challenges facing nuclear facilities today. Budgets are tight and developing, delivering and maintaining SAT training is expensive. And, as training costs continue to rise, opportunities for reducing costs are continuingly being sought. It is essential in this climate to continue to develop competent personnel and ensure quality is maintained.

Training, using the SAT model, should meet any and all regulatory requirements, be seen to add value to an organization and not be seen as bureaucratic, resource intensive, or complex to manage. In sum, the use of a graded approach to SAT should, when well applied, deliver performance improvements and accident reduction rates (nuclear and personnel) for a nuclear facility.

When developing new training programmes or making significant changes to an existing programme, early contact or involvement with the relevant regulator is suggested.

Again, implementing a graded approach to SAT can reduce the cost of training development and demands on critical resources whilst maintaining quality and delivering performance improvements. Negative perceptions of the line and senior management can be addressed and a return on the investment can be demonstrated by:

- Developing training in a shorter duration than using full SAT for all roles/tasks and thus delivering results faster;
- Maintaining a competent workforce;
- Shortening the training duration by only training on what is needed and not what is nice to have;
- Reducing time of personnel away from the workplace;
- Removing unnecessary paperwork;
- Optimizing approval requirements.

Technology has advanced considerably over the past few years and training tools, such as eLearning and Learning Management Systems, have been developed which support the delivery and management of training programmes. Such tools can assist in reducing the training organization workload and help in reducing the overall costs of SAT based training.

When considering the content of this document, it is clear that there may be two distinct steps in the graded approach: The first step is to grade, or categorize, jobs or positions according to their safety (or sometimes performance) significance; and the second, based on the grading of positions, is to determine what level of SAT to apply. This document contains a number of case studies provided by Member States showing real-life examples of where both steps have been completed, and some of them focused more on the grading of positions rather than the grading of the SAT process itself.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Systematic Approach to Training for Nuclear Facility Personnel: Processes, Methodology and Practices, IAEA Nuclear Energy Series No. NG-T-2.8, IAEA, Vienna (2021).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Fundamental Safety Principles, Safety Fundamentals, IAEA Safety Standards Series, No. SF-1, IAEA, Vienna (2006).

[3] WORLD NUCLEAR ASSOCIATION, World Nuclear Performance Report 2020 No. 2020/008, WNA, (2020).

[4] INSTITUTE OF NUCLEAR POWER OPERATIONS, The Objectives and Criteria for Accreditation of Training in the Nuclear Power Industry, National Academy for Nuclear Training, INPO ACAD 02-001 rev. 1, (2002).

[5] INSTITUTE OF NUCLEAR POWER OPERATIONS Guidelines for Training and Qualification of Engineering Personnel, National Academy for Nuclear Training, INPO ACAD 98-004 rev. 4, (2009).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Managing Regulatory Body Competence, Safety Reports Series No. 79, IAEA, Vienna (2014).

ANNEX: CONTENTS OF THE SUPPLEMENTARY ELECTRONIC FILES

Supplementary electronic file ‘Graded Approach Flow Chart’ is available on IAEA pages https://www.iaea.org/publications.

The flow chart provides some examples of activities and efficiency adjustments to consider when initially selecting or re-evaluating the grade at which to apply SAT.

ABBREVIATIONS

ADDIE	analysis, design, develop, implement and evaluate
ALARA	as low as reasonably achievable
BWR	boiling water reactor
BWROG	boiling water reactor owner group
CBT	computer-based testing
CNEA	National Atomic Energy Commission of Argentina
CSN	Consejo de Seguridad Nuclear
DACUM	developing a curriculum
DOE	Department of Energy
DIF	difficulty, importance, and frequency
EOP	emergency operating procedures
EPC	emergency procedure committee
ERO	emergency response organization
GEH	General Electric Hitachi
HAZOP	hazard and operability study
IAEA	International Atomic Energy Agency
IMS	integrated management system
INPO	Institute of Nuclear Power Operations
INPRO	international project on innovative nuclear reactors and fuel cycles
JCA	job competence analysis
JTA	job task analysis
KBA	knowledge based analysis
KINS	Korea Institute of Nuclear Safety
KPI	key performance indicator
KSA	knowledge, skills and attitudes
LMS	learning management system
NPP	nuclear power plant
PBT	paper-based testing
PSA	probabilistic safety assessment
QA	quadrant competence area
RP	radiation protection
SAIL	severe accident interactive learning
SAT	systematic approach to training
SAMG	severe accident management guidelines

SME	subject matter expert
TBA	task based analysis
TECDOC	technical document
WANO	World Association of Nuclear Operators

CONTRIBUTORS TO DRAFTING AND REVIEW

Alvarenga, M.A.B.	Comissao Nacional de Energia Nuclear (CNEN), Brazil
Balayan, V.	HAEK CJSC, Armenia
Berry, P.	Consultant, USA
Botta Chevreau, C.H.M.	EDF, France
Cakir, E.	Nuclear Regulatory Authority, Türkiye
Cotiga, C. A.	SN "Nuclearelectrica" S.A., Cernavoda Nuclear Power Plant, Romania
Delgado Criado, J.L.	Tecnatom, Spain
Demko, M.	IAEA
Dieguez Porras, P.	IAEA
Fraguas, F.	Nucleoelectrica Argentina, Argentina
Gonzalez Rabasa, D.	ANAV Asco & Vandellos II NPP, Spain
Květoňová, R.	IAEA
Lee, J.H.	Korea Institute of Nuclear Safety, Republic of Korea
Lopez, M.P.	National Energy Commission, Argentina
Lu, Y.	CNNC Nuclear Power Operations Management Co. Ltd., China
Molloy, B.	Consultant, Ireland
Naylor, S.	Consultant, United Kingdom
Page, S.	EDF, United Kingdom
Suarez, F.O.	Tecnatom, Spain
Williams, L.	EDF, United Kingdom
Valle Cepero, R.	Nuclear Regulatory Authority, Argentina
Vesely, M.	Canadian Nuclear Safety Commission (CNSC), Canada
Zhou, Y.	Jiangsu nuclear Power Corporation (JNPC), China

Technical Meeting

Vienna, Austria: 7-10 November 2022

Consultancy Meetings

22-25 November 2021, 21 – 23 March 2022, 25 – 28 April 2023

Vienna, Austria

IAEA
International Atomic Energy Agency

CONTACT IAEA PUBLISHING

Feedback on IAEA publications may be given via the on-line form available at:
www.iaea.org/publications/feedback

This form may also be used to report safety issues or environmental queries concerning IAEA publications.

Alternatively, contact IAEA Publishing:

Publishing Section
International Atomic Energy Agency
Vienna International Centre, PO Box 100, 1400 Vienna, Austria
Telephone: +43 1 2600 22529 or 22530
Email: sales.publications@iaea.org
www.iaea.org/publications

Priced and unpriced IAEA publications may be ordered directly from the IAEA.

ORDERING LOCALLY

Priced IAEA publications may be purchased from regional distributors and from major local booksellers.

25-00578E