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HOW THE NUCLEAR SAFETY TEAM CONDUCTS EMERGENCY EXERCISES AT THE IEA-R1 REACTOR

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ABSTRACT

This work introduces the *Diagram* of *Emergency Exercise Coordination* designed by the *Nuclear Safety Team* for better *Emergency Exercise* coordination. The *Nuclear Safety Team* was created with the mission of avoiding, preventing and mitigating the causes and effects of accidents at the IEA-R1. The facility where we conduct our work is located in an area of a huge population, what increases the responsibility of our mission: conducting exercises and training are part of our daily activities. During the *Emergency Exercise*, accidents ranked 0-4 on INES (International Nuclear Events Scale) are simulated and involve: Police Department, Fire Department, workers, people from the community, and others. In the last exercise held in June 2014, the scenario contemplated a terrorist organization action that infiltrated in a group of students who were visiting the IEA-R1, tried to steal fresh fuel element to fabricate a dirty bomb. Emergency procedures and plans, timeline and metrics of the actions were applied to the *Emergency Exercise* evaluation. The next exercise will be held in November, with the simulation of the piping of the primary cooling circuit rupture, causing the emptying of the pool and the lack of cooling of the fuel elements in the reactor core: this will be the scenario. The skills acquired and the systems improvement have been very important tools for the reactor operation safety and the Nuclear *Safety Team* is making technical efforts so that these *Emergency Exercises may be applied to* other nuclear and radiological facilities. Equally important for the process of improving nuclear safety is the emphasis placed on implementing quality improvements to the human factor in the nuclear safety area, a crucial element that is often not considered by those outside the nuclear sector. Surely, the *Diagram* of *Emergency Exercise Coordination* application will improve and facilitate the organization, coordination and evaluation tasks.

1. INTRODUCTION

The IEA-R1 Nuclear Research Reactor-NRR started operation in 1957, it was constructed by Babcock-Wilcox and it is a pool type reactor, moderated and cooled by light water, using beryllium reflectors. It operates 64 h per week at a thermal power of 5MW, by a forty-people team, including operators and radiological protection personnel. It is located in the *Instituto de Pesquisas Energéticas e Nucleares* (IPEN-CNEN/S.P), at the University of São Paulo (USP) campus. The IEA-R1 is the only research reactor in Brazil with power level suitable for utilization in scientific analytical work and research in physics, chemistry, biology and engineering, as well as for producing some useful radioisotopes for medical and industrial applications. The implantation of an integrated management system including quality assurance, safety culture and environmental consciousness is essential for the reactor operation, maintenance and irradiation services. Designing the *Diagram of Emergency Exercise Coordination-DEECo*, the *Nuclear Safety Team-NST* provided us with a better way for the *Emergency Exercise-EEx* organization. The NST is composed by experts on areas of physical protection, radiological protection, worker safety and fire prevention and it was created with the mission to prevent, avoid and mitigate accidents in the facility, always aware of the human factor [1,26]. Surely, the EEx is the best tool to prepare people and make them ready for an emergency [2], spreading the importance of nuclear technology for the future generations and the safety culture is, definitely, one of our goals. The DEECo was presented for the first time on the "*International Experts Meeting on Assessment and Prognosis in Response to a Nuclear or Radiological Emergency*", 20-24 April, 2015 at the IAEA-Vienna [3]; after the implementation of suggestions by safety and security experts from Canada and France, the diagram has undergone some changes, but it still maintains the original ideas.

2. METHODOLOGY

The DEECo was designed in nine sections (Figure 1), all of them including activities, people, documents and equipment present at the EEx in IEA-R1. Preparedness and response for a fast action in emergency situation is necessary to avoid that a local emergency becomes a general emergency [4]. At the first reunion after NST creation [5], EEx was declared the best way to practice our diary safety activities.

2.1. Emergency Exercise (EEx)

While the likelihood of a severe nuclear accident in our facility is low, exercise is designed to allow that all the organizations involved, local, state and federal can address the simulated accident’s effects on the economy, environment and public health and be better prepared to respond if the events were real. After global warming [6], the coming nuclear renaissance around the world and the expected retirement of a high percentage of nuclear technical experts in the near future, it is more important than ever that we develop a pipeline that is capable of producing the next generation of nuclear security professionals. We need to attract, recruit and train top university students and diverse professionals in the field of nuclear nonproliferation, international safeguards, related nuclear security fields and INPRO (*International Project on Innovative Nuclear Reactors and Fuel Cycles*) methodologies [7]. Such students, whether focused on technology or security policy, will require an interdisciplinary education that includes a solid basis on policy, science, and technology. Nuclear safety missions demand educated and trained professionals that understand not only the technology, but also the complex interplay of the technology with the policy and legal frameworks of nuclear security applications. It will require a culture of partnership and collaboration across academia, government and industry to effective create this strategic pipeline [8,25]. A physical protection system designed only for today’s threat may not be effective against tomorrow’s threat [9,28].

2.2. Scenario

Based on *Design Basis Threat* (DBT) [10, 12] and *Design Basis Accident* (DBA) we have written EEx scenario (Figure 2). After Fukushima Daiichi Nuclear Power Plant accident, the IAEA issued documents with recommendation regarding extreme emergency situations [11].

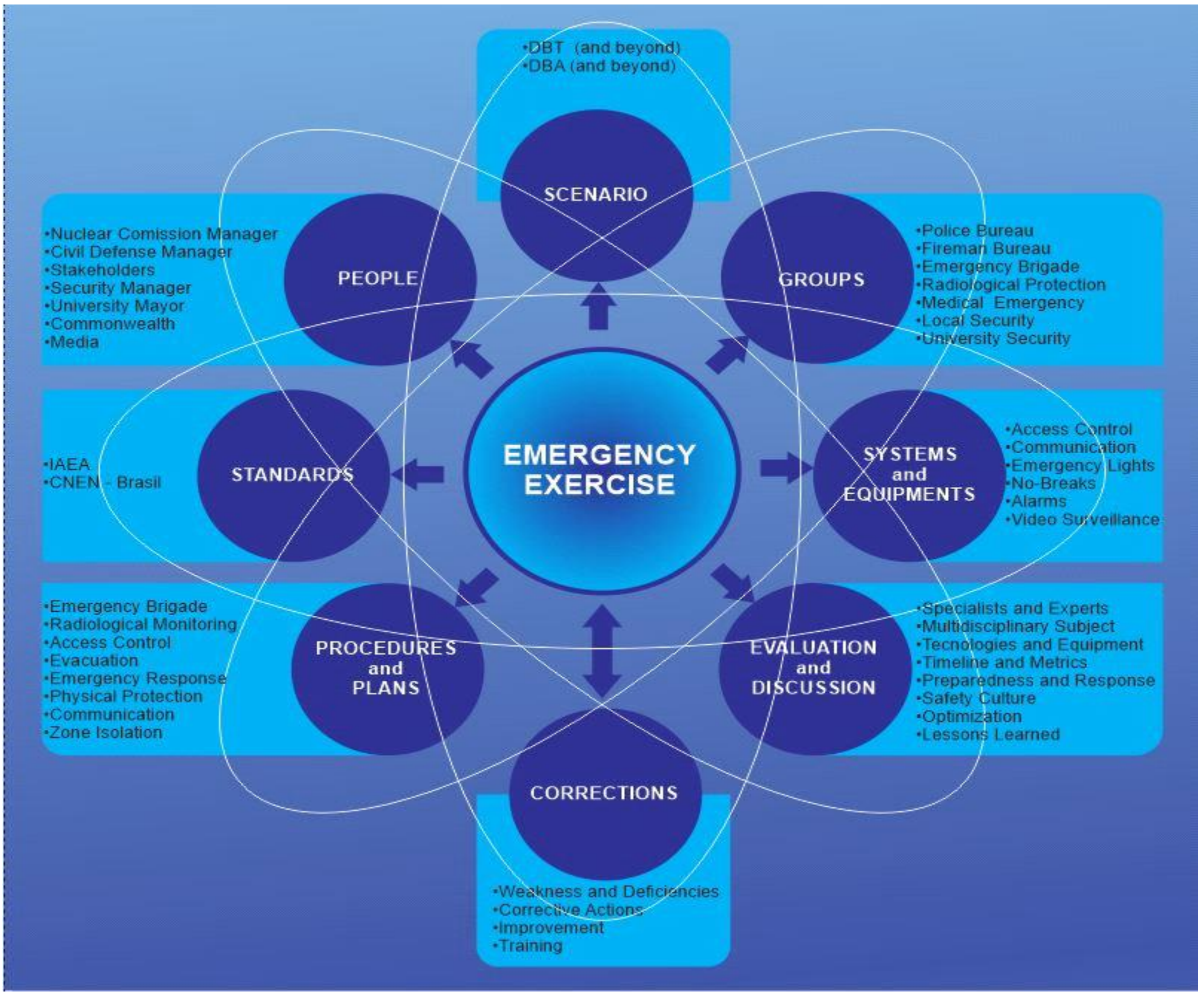

Figure 1: Diagram of Emergency Exercise Coordination (DEECo)

Hence, any *Loss of Cooling Accident* (LOCA) and reactor confinement, despite consequences, is considered a severe accident. A DBT is a comprehensive description of the motivation, intention and capabilities of potential adversaries against which protection systems are designed and evaluated: such definition permits security planning on the basis of risk management. A DBT is derived from credible intelligent information and other data concerning threats, but it is not intended to be a statement about actual, prevailing threats. Historically, States have used DBT´s in their regulatory system to achieve appropriate allocation of resources for the protection of nuclear material and nuclear facilities against malicious acts by potential adversaries that could result in high consequences, particularly radiological consequences. In the absence of a sufficiently detailed and accurate description of the threat, it is difficult to determine, with precision, the amount of protection that would be appropriate and effective for a given facility or activity in order to prevent unacceptable consequences from an adversary. Given the potentially severe consequences of some malicious acts and the high costs of providing protection, uncertainties about the threat are unlikely to be acceptable to any "State Authorities" who are responsible for deciding how much protection is appropriate. Without a well specified description of the threat, it may be very difficult to determine with confidence whether protection is adequate and sufficient. At the operator level, methods of detection, measures for delay and the composition of the response to malicious acts should be developed to address the adversary capabilities described in the DBT. In short, the physical protection system, and each of the measures that comprise the system, should be developed in the light of, and assessed in terms of the DBT. DBA is a description [12] of conditions against which a facility is, according to established design criteria, and for which the damage to the fuel and the release of radioactive material are maintained within authorized limits.

Figure 2: Scenario performed on EEx-2014

2.3. Groups

A group leaders meeting is very important to introduce the scenario and define the exercise date and time for procedures revision, as well. The groups involved have the opportunity to give opinion about the scenario and evaluate the schedules of exercise dates. The groups are: Police Dept., Fire Dept., Civil Defense Manager, São Paulo University Security Manager, Traffic Dept., Expert Observer (Figure 3), Emergency Brigade and Medical Emergency [13].

2.4. People

This section is important regarding the significance of nuclear installations safety and security and for showing how useful nuclear technologies benefits are for the society. The personnel include IPEN's managers, CNEN commissary, stakeholders, media and people from the community [14,27].

2.5. Standards

Standards and some publications from CNEN and IAEA [15], documents which are important for procedures and plans elaboration:

- Physical Protection of Nuclear Facilities (CNEN NE-2.01)

- Nuclear Materials Control (CNEN NN-2.02)
- Fire Protection for Nuclear Power Plants (CNEN NE-2.04)
- Transport of Radioactive Materials (CNEN NE-5.01)
- Licensing of Nuclear Reactor Operators (RES CNEN 109/11)
- Health Requirements for Nuclear Reactor Operators (CNEN NE-1.06)
- Development, Use and Maintenance of Design Basis Threat (IAEA Publication)
- Code of Conduct on the Safety of Research Reactors (IAEA Publication)
- Physical Protection of Nuclear Material and Nuclear Facilities-INFCIRC/225/Rev.05 (IAEA Recommendation).
- Safety Culture in Nuclear Installations (IAEA Publication).

Today, regulatory requirements for new plants demand that the effects of any core melt accident should be confined to the plant itself, without the need to evacuate nearby residents.

Figure 3: Expert observer on EEx-2014

2.6. Systems and Equipment

It covers the fire protection system, radiological protection system, surveillance video system, communication system, radiation detectors, metal detectors, walkie-talkies and grounding system for a better EMC (*Electromagnetic Compatibility*) [16]. Optimization of technology applications for a better safety performance, like FPGA technology (*Field Programmable Gate Array*) [17], a new I&C system for the IEA-R1 control room, measurements and sensing technologies play a fundamental role in the process of accident mitigation. The philosophy of safety systems is "defense-in-depth", with multiple safety systems supplementing the natural features of the reactor core. Key aspects of the approach for plans elaboration:

- High-quality design & construction,

- Equipment which prevents operational disturbances or human failures and errors developing into problems,
- Comprehensive monitoring and regular testing to detect equipment or operator failures,
- Redundant and diverse systems to control damage to the fuel and prevent significant radioactive releases,
- Provision to confine the effects of severe fuel damage (or any other problem).

These can be summed up as: prevention, monitoring and action (to mitigate consequences of failures).The safety and security provisions include a series of physical barriers between the radioactive reactor core and the environment, the provision of multiple safety systems, each with backup and designed to accommodate human error [18,19]. Safety and security systems account for about one quarter of the capital cost of such reactors. As well as the physical aspects of safety, there are institutional aspects which are not less important.

2.7. Procedures and Plans

The EEx is important to maintain people skills sharp and to identify areas for improvement. The exercises provide valuable experience and make the facility overall emergency response procedures and plans carry out well. The objective of this section is to check how workers are trained to follow the procedures and the safety and security culture through their every day behavior.

2.8. Evaluation and Discussion

Optimization, improvement, lessons learned and multidisciplinary subject are the paths. Multidisciplinary ideas try to show to society the destructive power of nuclear weapons, competing strongly with the constructive power of nuclear energy. The first steps of nuclear energy industry, over the last 50 years, proved that nuclear energy is the safest and most efficient of all energy sources, from both human health and environmental perspective, as well [20]. To produce a trillion kilowatt-hours of electricity, nuclear takes less land, uses less steel and concrete, kills fewer people and has less harmful emissions than any other energy source, including wind and solar.

2.9. Corrections

It is the phase which works to maintain and improve nuclear safety and security: it is a continuous process and requires ongoing attention.

3. CONCLUSIONS

The DEECo gave us an overview of the exercise complexity and the safety and security depend on the coordinated actions of the various groups involved. With the participation and support from leaders and managers, our work can be developed in the best way. The NST creation is important to improve the safety and security of the IEA-R1 reactor facility. As the group has experts in physical protection, radiological protection, work safety and fire protection, we have conditions to be prepared and to have a reliable response in the case of a nuclear emergency. The team is strengthening efforts to perform emergency exercises in other nuclear and radiological facilities [21]. We are concerned to protect the future against nuclear threats and this is a daunting challenge and a critical area in which national and international programs must provide sustainable actions. Agreements to lessen nuclear threats, hackers and drones are considered the new challenge for nuclear industry [22,23] and should be approached under the IAEA and CNEN standards revision. Certainly, had emergency exercises, with the scenario of severe accidents, been conducted in Chernobyl and Fukushima Daiichi Power Plants [24], damages to the environment and society would have been much smaller than the data presented so far: nuclear reactor accidents constitute an epitome of low-probability but high-consequence risks. Brazil needs to contribute, actively, to the international development of a nuclear security policy.

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