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The Impact of Implementing the Design Basis Threat Concept on the Regulatory Infrastructure of the Brazilian Nuclear Sector: Analysis and Perspectives

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Abstract: Fundamental Principle G of the 2005 Amendment to the Convention on the Physical Protection of Nuclear Material, ratified by Brazil in 2022, guided the conceptual development of the Design Basis Threat (DBT) and justified the proposal for its implementation in the Brazilian nuclear regulatory framework. The first step in the implementation process, coordinated by the Directorate for Safety, Security, and Safeguard of the Brazilian National Nuclear Energy Commission, is the regulatory impact analysis, a qualitative analysis based on reviewing international and national documents and institutional procedures. In addition to the regulatory impact analysis, an action plan and proposals for the creation of new documents were structured. It was concluded that the DBT concept implementation would allow the transition of the regulatory approach, the optimization, and expansion of the protection of selected critical facilities, the centralization of the definition of threats by the State, ensuring strategic coherence and reducing operational gaps previously associated with fragmented responsibility; and the creation of new documents such as the National Threat Report, resulting from the interaction between the public security sector, the regulator and operators.

Keywords: design basis threat, nuclear security, nuclear regulation, nuclear facilities.

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O Impacto da Implementação do Conceito de Ameaça Base de Projeto na Infraestrutura Regulatória do Setor Nuclear Brasileiro: Análise e Perspectivas

Resumo: O Princípio Fundamental G da Emenda à Convenção de Proteção Física para Materiais Nucleares (A/CPPNM) de 2005, ratificada pelo Brasil em 2022, direcionou o desenvolvimento conceitual da Ameaça Base de Projeto (ABP) e justificou a proposta de sua implementação no arcabouço regulatório nuclear brasileiro. O primeiro ato do processo de implementação, coordenado pela Diretoria de Radioproteção e Segurança Nuclear da Comissão Nacional de Energia Nuclear, é a análise do impacto regulatório, uma análise qualitativa, baseada na revisão de documentos internacionais, nacionais e dos procedimentos institucionais. Além da análise de impacto regulatório, foi estruturado um plano de ação e propostas para a criação de novos documentos. Concluiu-se que a implementação do conceito da ABP permitiria: a transição da abordagem regulatória; a otimização e a ampliação da proteção das instalações críticas selecionadas; a centralização da definição de ameaças pelo Estado, garantindo coerência estratégica e reduzindo lacunas operacionais anteriormente associadas à responsabilidade fragmentada; e a criação de novos documentos como o Relatório Nacional de Ameaças, proveniente da interação entre o setor da segurança pública com o regulador e os operadores.

Palavras-chave: segurança física nuclear, ameaça base de projeto, regulação nuclear, instalações nucleares.

1. INTRODUCTION

The discovery of radiation by Henri Becquerel at the end of the 19th century [1] marked the beginning of a series of applications involving radioactive materials in various areas, such as medicine, industry, and energy generation. However, the expansion of these applications revealed significant risks, requiring the development of safety systems to minimize the possibility of events occurring that could affect humans and the environment.

Years later, in the 20th century, as a result of the nuclear technology evolution and its applications, the International Atomic Energy Agency (IAEA) was created in 1957, in the Cold War context, under the auspices of the United Nations (UN), with the three-fold mission of fostering international technical cooperation, promoting the adoption of nuclear control and safeguard measures, and strengthening nuclear safety. Among these, the dissemination of nuclear security among Member States stands out, with the 1979 Convention on the Physical Protection of Nuclear Material (CPPNM) as its primary reference.

In the 21st century, the September 11, 2001, attack on the World Trade Center accelerated reforms in the international nuclear security regime, as the potential use of radioactive sources in terrorist attacks demanded greater regulatory rigor. This event significantly contributed to the publication of the Amendment to the CPPNM (A/CPPNM) of 2005 [2], structured in 12 fundamental principles, which became mandatory for Member States as of 2016. Brazil ratified the text of the Amendment through the Presidency of the Republic Decree Nº 11188 of September 5, 2022 [3].

In Brazil, in 1956, the Brazilian National Nuclear Energy Commission (CNEN) was created, a federal agency with the following institutional purposes:

I. to collaborate in the formulation of the National Nuclear Energy Policy;

II. to carry out research, development, promotion, and service provision actions in the nuclear technology area and its applications for peaceful purposes; and

III. to regulate, license, authorize, control, and monitor this use.

CNEN has a dedicated department that handles all matters related to licensing, standardization, and inspection of the radioactive and nuclear sector: the Directorate for Safety, Security, and Safeguards (DRS). DRS is tasked with developing and implementing the regulatory framework for the Brazilian nuclear industry. In 1972, it published the first standard that incorporated security criteria: "Nuclear Power Reactor Licensing Standards," and shortly thereafter, in 1977, it released the first standard that specifically addressed the topic: "CNEN Standard NE 2.01 - Physical Protection of Nuclear Power Installations" [4].

In 2021, the law creating the National Nuclear Safety Authority (ANSN) [5] was enacted, which is responsible for exercising the third institutional purpose of the CNEN: regulating, licensing, authorizing, controlling, and monitoring the use of nuclear and radioactive materials. Structurally, the law transformed the DRS into an independent federal agency, but its implementation still requires government measures from the Legislative and Executive Branches.

Fundamental Principle G (Threat) of the A/CPPNM recommends that the nuclear security regime of States should be based on an updated threat assessment conducted by the State itself. The Design Basis Threat (DBT) concept was developed to operationalize this responsibility, which involves identifying and assessing threats to facilities. This provides a crucial foundation for selecting, designing, and implementing physical protection actions and measures for nuclear or other radioactive materials, facilities, and associated activities. The results of this identification and assessment are documented, detailing potential adversaries' motivations, intentions, and capabilities that must be addressed to protect materials, facilities, and associated activities, considering both physical and cyber threats [6].

In Brazil, regulations only provide for operators' responsibility in preparing for this threat, which is used to size the entire physical protection system of the facility, which can lead to undersized systems. Another problem that can affect the sizing of systems is regulatory rigidity with its prescriptive requirements, which treat security system installations and different radiological risks in the same way.

Since 2018, the Office of Nuclear Security (ESF), together with the Standards Sector (SENOR), both from the Nuclear Security and Standardization Division (DISEN/DRS/CNEN), has coordinated the incorporation of the DBT concept into the regulatory infrastructure through an interagency process: the DBT Process. This process aims to increase the effectiveness of the national security regime following the recommendations of the IAEA and Tavares [7], which defines nuclear security as a process that involves technologies, people, organizations, and a regulatory framework that must reflect the aspirations of society in protecting facilities, people and the environment against the potentially catastrophic effects of theft or sabotage actions involving nuclear materials and facilities.

1.1. Objective

This article analyzes the impacts of DBT insertion in the Brazilian regulatory infrastructure, identifying affected documents, regulatory gaps, and institutional processes involved.

2. MATERIALS AND METHODS

The study adopted a qualitative approach based on document review and regulatory impact analysis. The following were analyzed:

1. International documents: A/CPPNM (2005), IAEA guides (NSS Nº 10-G, NSS Nº 13) and technical reports.

2. National standards: CNEN NN 2.01, CNEN NN 2.05, and other standards of Group 2.

3. Institutional processes: DISEN/DRS/CNEN's role in coordinating the DBT Process, reviewing, and creating documents.

The analysis followed the following steps:

• Assessment of impacts on licensing processes;

• Identification of standards and regulatory gaps;

• Proposal of new documents and performance-based requirements.

3. RESULTS AND DISCUSSIONS

The State must conduct a comprehensive regulatory impact assessment before including the new concept in its regulatory framework. This analysis identifies institutional processes, standards, and affected stakeholders, ensuring that changes are aligned with strategic nuclear security objectives and international guidelines.

The following considerations were taken into account in the regulatory impact analysis, among other points:

• Legal aspects. Based on the binding text of the Amendment (A/CPPNM), IAEA guidance documents, and Brazilian legislation;

• Responsibilities and those affected. Responsibility of the State and operators, and the consequences for the general public;

• Economic impact. No impact on the State and operators;

• Training and knowledge exchange. Specific partnerships were established to train civil servants and operators on the subject, such as with the National Nuclear Security Administration (NNSA/USA), in addition to the IAEA;

• Timeframe. Both for implementing the concept in the regulatory infrastructure and for operationalization by operators;

• Regulatory risks. The possibility of loss of efficiency of the facilities' physical protection systems;

3.1. Definition and regulatory space of the DBT

The DBT, as defined by the IAEA Glossary [8], consists of the characterization of potential adversaries (internal/external) capable of unauthorized removal of nuclear materials or sabotage against facilities and activities. Its operationalization aims to:

• Strengthen the nuclear security of nuclear facilities and activities;

• Align Brazil with advanced nuclear security practices, such as those established in the Nuclear Security Series Nº 10-G [6].

In Brazil, the concept of threat, a structural theme for nuclear security, is included in Group 2 of the CNEN regulatory framework "Control of Nuclear Materials, Physical Protection and Fire Protection" [9], which brings together critical standards for risk mitigation.

3.1.1 Impacted regulatory documents

The DBT integration will require revisions to national standards, with emphasis on:

• Broad Scope Standards:

CNEN NE 1.04 (Licensing of Nuclear Installations);

CNEN NN 6.02 (Licensing of Radiation Installations).

• Specific Standards:

CNEN NN 2.01 (Physical Protection of Nuclear Materials and Installations) – main insertion route due to alignment with the A/CPPNM;

CNEN NN 2.05 (Physical Protection in the Transportation of Nuclear Materials and Other Radioactive Materials);

CNEN NN 2.07 (Cybersecurity of Nuclear and Radioactive Installations), applicable to critical scenarios.

The CNEN NN 2.01 Standard was the first document to receive the DBT concept by name in the national regulatory framework, which reflects the direction of the main industry document on nuclear security: A/CPPNM, and of specific auxiliary documents such as the implementation guide NSS Nº 10-G "National Assessment of Nuclear Security Threats, Design-Based Threats and Representative Threat Declarations" and the recommendations guide NSS Nº 13 "Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities", both IAEA documents that point to the application of this concept to the main facilities and activities of the nuclear sector. This standard, via the DBT concept, will also be used to conduct studies on hybrid requirements.

The second document affected will be Standard CNEN NN 2.05 "Physical Protection in the Transportation of Nuclear Materials and Other Radioactive Materials", which refers to the activity of transporting nuclear materials and also uses the concept if it is inserted in the context of a design-based threat. The State may consider applying this concept in other documents such as standards CNEN NN 2.06 and CNEN NN 2.07 "Cybersecurity of Nuclear and Radioactive Installations", because even though the focus is on the nuclear sector, there are specific scenarios where the State, armed with its duty towards collective security, may apply this concept to specific radioactive installations, or even apply part of the process that will be developed for nuclear installations to radioactive installations, aiming at increasing the security of materials, the environment and, always, people.

3.2. Responsibilities, gaps, and solutions

3.1.2 Responsibilities

The responsibility for developing, implementing, maintaining, and reviewing this concept lies with the State, which reflects international documents, the main one being the Amendment to the Convention on the Physical Protection of Nuclear Material, which establishes in its first principle:

> "Fundamental Principle A: State Responsibility. The responsibility for establishing, implementing and maintaining a physical protection regime within a State lies entirely with that State." [2]

DRS/CNEN, the coordinator of the implementation process, should seek support from other institutions, as this process requires specific information outside the regulatory body, which includes topics related to public and state safety, as well as the collection and analysis of sensitive information, mainly classified as confidential or has restricted access. The responsibility for operationalizing the concept in their physical protection systems remains with the operators, who may request technical reviews on the DBT from DRS/CNEN.

3.1.3 Gaps and solutions

Due to the evolution of concepts, practices, and technologies in the nuclear sector, gaps have emerged between the materialization of the State's responsibility and the operationalization of international best practices and recommendations. One of the gaps is in the Physical Protection Plan (PPF), which requires the facility to periodically submit to DRS/CNEN as one of the conditions for operating authorization. One of the PPF topics is the threat estimate used to size the Physical Protection System of the facilities, which until now was the responsibility of the operators themselves, regardless of the facility classification or the associated radiological risk. This situation can lead to two deficiencies:

1. Homogenization of Risks: Prescriptive standards treated high and medium-risk facilities equally, resulting in undersized protection systems.

2. Fragmentation in the Definition of Threats: Operators made threat estimates without unified criteria.

With the DBT Process, the State begins to select the country's main facilities based on well-defined criteria, such as the associated radiological risk and their strategic position for the country, making all its apparatus available to define, coordinate, and assist operators in the task of identifying, characterizing and classifying the main national and international threats, and thus, consolidating the most credible threat for a facility or several facilities, allowing the following optimizations:

• Risk-Based Classification: Prioritization of strategic facilities (e.g., nuclear power plants) based on radiological and geopolitical criteria;

• Hybrid Parameters: Introduction of performance criteria, complementing prescriptive approaches for customizing physical protection systems.

Risk-based classification allows the facility to scale its physical protection system more effectively, developing all necessary functions (detection, delay, and response) more appropriately when a physical security event occurs. Hybrid parameters allow the State to take a more individualized approach, normatively, to the physical protection systems of each facility. This more specific state view allows the use of particular parameters that better characterize the systems, thus directing the actions of both the State and the operator, seeking increasingly efficient systems. It is worth remembering that this approach is aimed at facilities with greater radiological risks and more complex physical protection systems.

3.2 New documents and protocols

In the DBT implementation process, in addition to the need to change some existing documents, such as CNEN NN 2.01, it will be necessary to create other documents, under the responsibility of different agencies participating in the process, highlighting:

1. Joint Action Plan: Defines the stages of the process, establishing attributions, responsibilities, and the methodology for implementing the process, including the

interfaces/dialogue between the participating institutions and, in particular, between the regulatory body and the operators.

2. National Threat Report: Prepared by intelligence agencies, it integrates domestic and international threats.

3. Detailed Attack Scenarios: Describe possible situations of adversarial attacks, which will serve to specify the response actions of the physical protection system.

4. Technical Protocols: Documents that describe vulnerabilities and performance parameters.

3.2.1 Joint Action Plan

The Joint Action Plan is the guideline for developing, implementing, and executing the DBT concept through a structured interagency process coordinated by the regulatory body. The regulatory body prepares the draft of the Joint Action Plan, but its validation requires the approval of the other participants in the process since the regulatory body does not have all the necessary tools to conduct the process. In this context, this Joint Action Plan aims to guide the actions of the actors involved in the process, considering that they are institutions with different attributions and, therefore, with other cultures. The implementation process can be divided into phases, as exemplified below, but this segmentation into phases will depend on several factors inherent to each country:

1. Phase 1: Interinstitutional validation of the Joint Action Plan, listing and prioritizing critical facilities where the process will be applied.

2. Phase 2: Identify and consolidate threats to facilities.

3. Phase 3: Preparation of scenarios, performance requirements, and verification of the need for regulatory review.

4. Phase 4: Review and maintenance.

In the last phase of process implementation, review, and maintenance, still coordinated by the regulatory body, a routine for continuous monitoring of the evolution of the threat scenario must be established, in addition to developing new performance parameters arising from research and innovation on the subject.

3.3 Future possibilities

With Phase 4 completed, the regulatory body, in addition to maintenance and regulatory research, will also seek to:

• Enhanced Hybrid Approach: Combining prescriptive and performance-based requirements to optimize nuclear security.

• International Cooperation: Partnerships with the IAEA and countries already developing a DBT.

• Investment in Training: Training professionals in vulnerability analysis and risk management.

4. CONCLUSIONS

The insertion of the Threat Basis Design (DBT) concept in the Brazilian regulatory infrastructure consolidates compliance with Fundamental Principle G "Threat", established by the Amendment to the Convention on the Physical Protection of Nuclear Material (A/CPPNM). By integrating this principle, Brazil complies with a binding international commitment and redefines its nuclear security paradigm, increasing dynamic and risk-based mechanisms in generic approaches. This change reflects the A/CPPNM guidelines, which require signatory States to adopt physical protection systems aligned with realistic and up-to-date threats.

The impacts of this integration are multifaceted: 1) the transition to hybrid requirements (prescriptive and performance) allows for the optimization of the protection of critical facilities, such as nuclear power plants; 2) the centralization of threat definition by the State ensures strategic coherence and reduces operational gaps previously associated with fragmented responsibility; and 3) the creation of documents such as the National Threat Report reinforces interoperability between intelligence, public security and regulators, following successful models from countries such as the United States and France.

By ratifying the A/CPPNM in 2022, Brazil positioned itself among the few nations capable of operationalizing Principle G, standing out for its regulatory compliance and leading position in the practical application of complex concepts. This leadership strengthens the country's international credibility in specialized international forums and expands its ability to influence global nuclear security agendas. To consolidate these advances, the following are recommended:

• Continuous monitoring of emerging threats (e.g., cyber, non-state terrorism);

• Expansion of technical partnerships with the IAEA and bilateral organizations to exchange best practices;

• Investment in training professionals in the nuclear sector, emphasizing vulnerability analysis and risk management.

In short, the DBT is not just a regulatory requirement but a milestone in the evolution of Brazilian nuclear security, aligning international principles with a strategic and proactive vision of national protection.

The implementation process of the DBT in Brazil, based on the Joint Action Plan, is currently in Phase 3, focusing on developing scenarios for the facilities selected for this process. The Office of Nuclear Security has opted to begin with the most critical nuclear facilities before expanding to transportation activities. During this implementation phase, the priority is to learn and establish procedures, then extend to the entire sector where feasible. Additionally, the knowledge gained by the Standards Sector regarding hybrid requirements can be applied to other areas beyond Nuclear Security.

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CONFLICT OF INTEREST

All authors declare no conflicts of interest.

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