Enhancing Research Reactor Safeguards Through the Use of Mailbox Declarations

A. Milojevich, J. Creasy, Y-12 National Security Complex

S. Martinson, Texas A&M University

ABSTRACT

INTRODUCTION

Research reactor safeguards are especially complex because of the multitude of types of reactors. Research reactors are designed to be flexible – they can operate in a wide range of configurations, significantly more than power reactors. Each design is unique to fit the needs of the operator and State. As such, the safeguards approaches for research reactors are not generalizable across reactors.

Previously, the IAEA utilized safeguards criteria for a given facility type, which attempted to apply similar safeguards concepts and approaches across a range of facilities. However, recent implementation of the State Level Concept (SLC) allows greater flexibility to apply the appropriate safeguards to a given facility within the State. Several studies have proposed mailbox declarations as one method to enhance safeguards for research reactors. This paper focuses on identifying the important data that could be sent as part of a mailbox declaration.

It is proposed that mailbox declarations for research reactors are complementary to the SLC and may be applied with a similar approach, matching the safeguards approach to the appropriate priority and risk level.

Background

Research reactors under IAEA safeguards have not, at least to date, been successfully misused to acquire kilogram quantities of weapons fissile material for nuclear weapons. However, several cases of misuse have occurred in which the reactor and/or materials at a facility were misused. The quantities of material clandestinely produced or diverted at safeguarded research reactors in these seven cases were quite small, orders of magnitude below the detection quantity goals for detection by IAEA safeguards[1].

One such example can be observed when looking at Libya's nuclear history. Between 1984 and 1990, Libya failed to report to the IAEA the fabrication and subsequent irradiation of several dozens of small uranium oxide (gram quantities) targets in the 10MWth Tajura Research Reactor. A portion of the irradiated targets were processed in the hot cells at an adjacent radiochemistry laboratory; in the end, plutonium was separated from at least two irradiated targets[2]. The extent of Libya's undeclared nuclear program was not fully known by the international community until 2003 when then leader Colonel Mu'ammar Qadhafi admitted that, in contravention of its obligations under the Treaty on the Non-proliferation of Nuclear Weapons (NPT), the State had been pursing nuclear fuel cycle technology that could contribute to a weapons program.[2]

Despite the small quantities produced, early detection of research reactor misuse might provide the attention necessary to expose or deter other elements of a States' undeclared activities[1]. Misuse of small quantities can be an indicator of further undeclared activities and can be a first step in a broader acquisition effort. For example, in the case of Libya, research reactor misuse preceded several other activities in their acquisition effort, such as enrichment technology.[2]

State Level Concept and Acquisition Path Analysis

The IAEA has transitioned from safeguards criteria based evaluations of facilities, to a State level approach (SLA) with a comprehensive evaluation of the combination of facilities and other factors within a State. The ability for the IAEA to conduct more holistic safeguards across a set of facilities and capabilities within a state gives more flexibility to each state and facility approach, and acquisition path analysis (APA) allows for a more complete view of how each factor contributes to safeguards risks, detection probabilities, and relative safeguards efforts. In the cases of States with research reactors, the majority of APA paths often share the research reactor as a dominant node in the acquisition pathway.

Research Reactor Operating Parameters

The operating parameters of each of hundreds of research reactors worldwide are each unique, and thus the effects of misuse will have unique effects and signatures on each reactor as well, as opposed to the more uniform features of each class of commercial power reactor. Many research reactors still have analog outputs and paper logs of the parameters of interest to the facility. Often, reactor power and capability also correlate to more advanced measurement and recording techniques at the facility, as higher power and more continuously used facilities tend to have more investment in the facility infrastructure, as well as more experiments, research, and material production activities. This provides both additional opportunities for facility misuse, as well as additional data which may be collected to deter misuse.

Since the agreement by the State, in which a research reactor is located, with the IAEA may be a comprehensive safeguards agreement (CSA), a CSA plus Additional Protocol (AP), or INFCIRC/66-type safeguards agreement. The degree to which the IAEA may inspect within the State, as well as the information which may be requested, vary significantly. The number of research reactors per safeguards agreement type are illustrated in Figure 1. In Figure 2, the distribution of research reactors by power level is displayed.

It is proposed that the mailbox declarable parameters and frequency are implemented to match the State and facility safeguards priority, as well as the IAEA's legal ability to inspect the facilities.

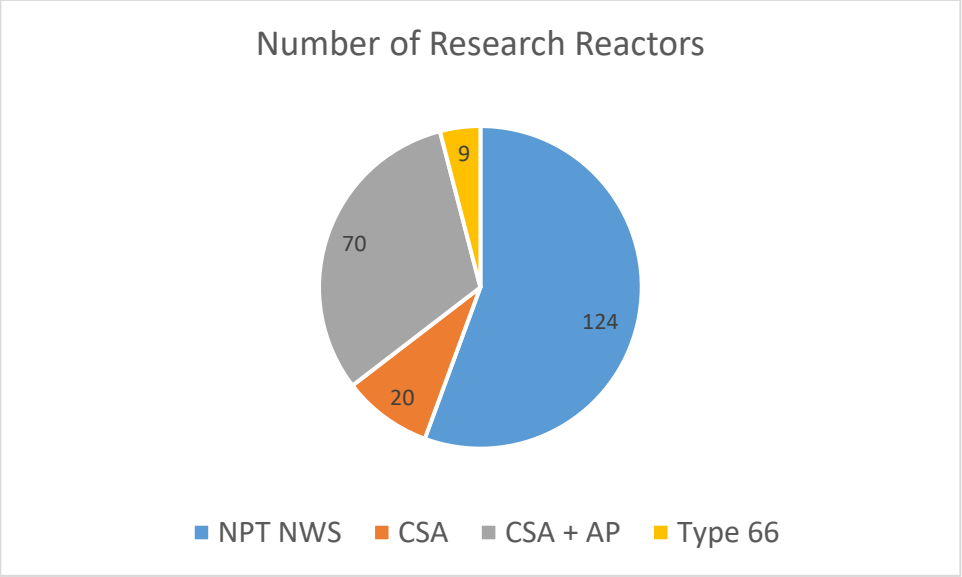

Figure 1. Distribution of research reactors worldwide, sorted by safeguards agreement.

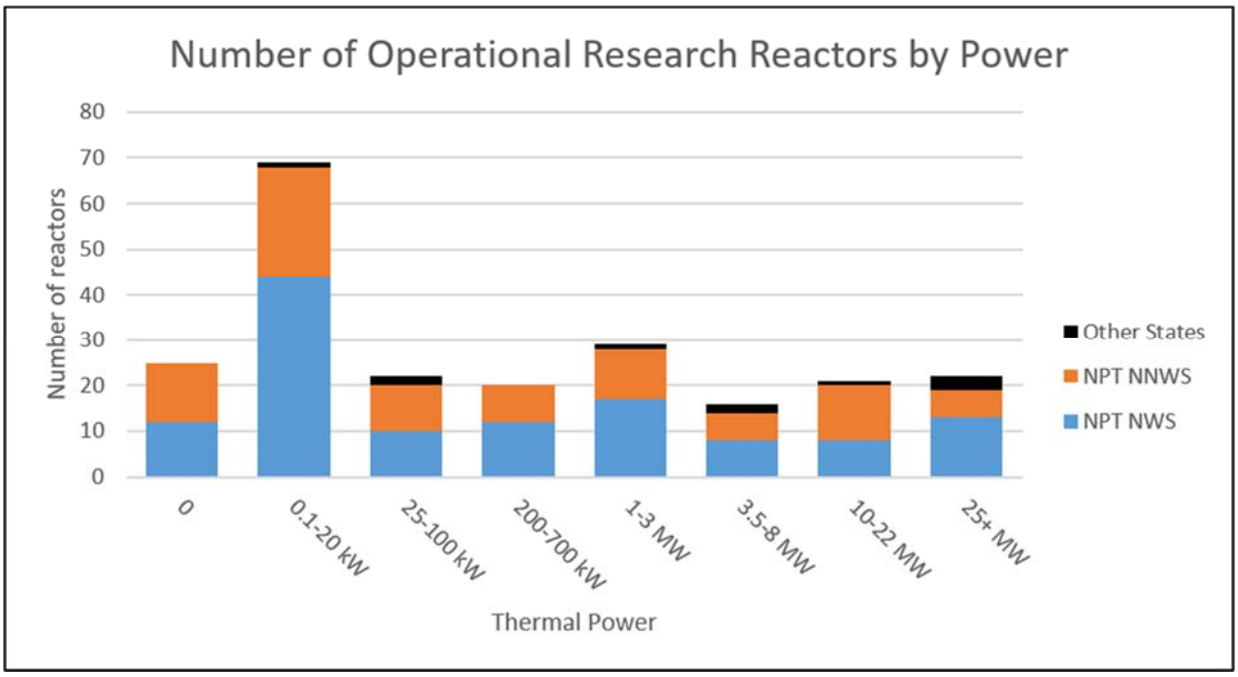

Figure 2. Research reactors worldwide, binned by power level.

Mailbox Declarations

Mailbox declarations are a secure information repository for collecting, and often transmitting, operator data, for the IAEA.[1] Once deposited in the mailbox, the data is considered immutable, and neither the IAEA nor the operator can change or remove the information.[3]

Mailbox declarations are currently used by the IAEA in some fuel cycle facilities, such as enrichment, on-load power reactors, and fuel fabrication. Currently mailbox declarations are not used for research reactors.

Mailbox Declaration Type and Frequency

Mailbox declarations are intended to increase confidence in the data being provided to the IAEA by the facility, and should not adversely affect facility operations. A graded, risk based approach, linked to the SLA for the State in which the reactor is located, is recommended to be used to determine the type of data, and frequency in which it is reported.

Table 1 gives proposed parameters to be declared, based on a priority level rating. The research reactor safeguards priority is related to the specifics of each research reactor, with lower safeguards priority research reactors reporting less frequently than the higher priority research reactors. Priority levels could be determined by a combination of factors including reactor power, nuclear material inventory, hot cell capabilities, and State specific factors.

Table 1. Proposed parameters to be declared versus safeguards priority level.

Declaration Type	Facility Priority Level		
	Low	Med	High
Operating time	X		
Startup/shutdown time		X	X
Daily average operating power		X	X
Average weekly control rod position	X		
Average daily control rod position		X	
Average hourly control rod position			X
Unscheduled shutdown time		X	X
Core fuel temperature		X	X
Coolant temperature		X	X
Coolant flow rate			X
Nuclear material movements within MBA	X	X	X

Number of targets/experiment positions used in core (including nuclear material, total reactivity)		X	X

From Table 1, it may be observed that reactor operating time is a separate declaration than startup and shutdown times. For lower safeguards priority reactors/facilities, a declaration of operating time and power may be integrated/added together by the operator for their declaration, while for medium and high safeguards priority reactors, a more detailed reactor operating history is desired.

It is proposed that control rod positions are declared with some granularity because they are sensitive to reactivity changes. Higher power research reactors typically already have more robust data acquisition systems, making mailbox declarations simpler to implement.

SCRAMS are important to note because when samples are inserted and removed, a reactivity spike or rapid reactivity loss may cause an unscheduled shutdown (SCRAM). SCRAM time stamps can be complementary to other data, such as control rod position trends, and may be indicative of undeclared material irradiation.

Core fuel temperature is often derived, and is often only directly measured in relatively lower power research reactors, such as TRIGA reactors.

Coolant temperature and flow rates are more important in situations where coolant is flowed over the reactor as compared to just in the pool. The combination of coolant temperature and flow rate may also be used to derive the reactor power. For example, the declared reactor power should correspond directly to the derived power from the temperature and flow rate, thus increasing confidence in the data.

Nuclear material movements in to and out of the material balance area (MBA) are already required to be declared under comprehensive safeguards agreements. However, nuclear material movements within an MBA are important to declare because movements between a reactor and a hot cell in the same MBA, for example, could indicate misuse of facility. These declarations also assist the IAEA in more effective short notice random inspections.

The ability to insert multiple targets/experiments and obfuscate undeclared nuclear material irradiations is a key concern for research reactors, and in medium and high priority facilities would be very important data for a mailbox declaration. It is recognized that this level of data collection may require additional effort by the operator and would need to be negotiated between the IAEA, State, and operator of the facility.

Table 2. Conceptual mailbox declaration frequency based on reactor safeguards priority level.

Mailbox Declaration Frequency	Safeguards Priority Level		
	Low	Med	High
Monthly	X		
Weekly		X	

Daily			X

Conceptual mailbox declaration frequency, as seen in Table 2, is related to both the safeguards timeliness goal and the data confidence timeliness goal. The safeguards timeliness goal is determined from the SLA, and the data confidence timeliness goal pertains to the importance of the data as an indicator and the impact of the data if falsified within a given time range. The suggested frequencies are based on minimizing the amount of time that a facility could potentially falsify the operational data between mailbox submittals.

Data Evaluation

While some data, like operating times and power, are valuable for understanding the potential for misuse of a research reactor (for example, more material movements and reactor operation outside of normal trends), additional data, such as control rod heights and reactor temperatures, provide support data which is expected to correlate to operating time and power and increase confidence in the data provided and the conclusions drawn.

Additional modeling is being performed by Texas A&M University to examine which parameters are of highest value for declaration. Preliminary data suggests that for some cases, for which parameters are on the order of past cases of misuse, control rod height may be a viable supporting indicator, as the negative reactivity insertion of undeclared targets may be observed in both the immediate time frame as well as longer term trends.

In the event that data from mailbox declarations are not self-consistent, or do not align with observations during inspections, then the IAEA would follow up in the standard progression of investigation of findings which may lead to a finding of noncompliance. This is discussed in a more comprehensive set of publications by CNS Y-12.

While the inspection frequency is not expected to reduce significantly for research reactors under safeguards, the effort to evaluate the safeguards data, both from Vienna and in the field, is anticipated to be significantly streamlined by utilizing mailbox declarations. A metric of success for mailbox declaration implementation is not simply a reduction in the number of person days in field (PDI), but also the effectiveness of those inspections.

Unattended Monitoring and Near Real Time Systems

The IAEA utilizes unattended monitoring systems (UMS) to remotely record and process various data from monitored facilities, including neutron and gamma radiation for presence, material movement, and identification, coolant temperature and flow rates, triggers, electrical power monitoring, and fluid levels. The UMS systems often act as the nexus for seals and surveillance data that is co-collected at the facility.

In some higher power research reactors, UMS systems to monitor coolant temperature and flow rate are installed to independently assess reactor power. In other cases, systems to monitor neutron emission from the reactor core are used to monitor core operating time and power.

UMS systems may be leveraged in a complementary manner to mailbox declarations. The IAEA may be able to see questionable trends and take more rapid action than if utilizing solely UMS or mailbox declarations.

Near-real time (NRT) is a relatively new concept within the IAEA which couples and automates some analysis of the mailbox declarations and unattended monitoring systems to provide rapid verification of mailbox declared data against observations by the UMS detectors. Although deployments of NRT systems are in their infancy, they are anticipated to see more widespread deployment and may be of value for some research reactor mailbox declarations.

SUMMARY

The IAEA State Level Concept takes an important step in consistently applying appropriate safeguards across a state and is maturing. An important next step in this maturation is deployment of strengthened safeguards techniques, including mailbox declarations. Mailbox declarations offer higher confidence in safeguards effectiveness and reduce the workload required of IAEA staff, especially in the post-inspection processing and assessment. This paper proposes a series of data that could be included in mailbox declarations, coupled with a graded approach based on facility priority, to better assure efficient and effective safeguards.

[1] Pacific Northwest National Laboratory. *Strengthening IAEA Safeguards for Research Reactors.* 2016. Available at https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-25885.pdf

[2] Nuclear Threat Initiative. Libya. Available at https://www.nti.org/learn/countries/libya/nuclear

[3] International Atomic Energy Agency. *Safeguards Implementation Practices Guide on Provision of Information to the IAEA*. Vienna. 2016