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Enhancing Efficiency of Safeguards at Facilities that are Shutdown or Closed-Down, including Those being Decommissioned

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2. Executive Summary

International Atomic Energy Agency (IAEA) safeguards involves verification activities at a wide range of facilities in a variety of operational phases (e.g., under construction, start-up, operating, shutdown, closed-down, and decommissioned). Safeguards optimization for each different facility type and operational phase is essential for the effectiveness of safeguards implementation. The IAEA's current guidance regarding safeguards for the different facility types in the various lifecycle phases is provided in its Design Information Examination (DIE) and Verification (DIV) procedure.¹

Greater efficiency in safeguarding facilities that are shut down or closed down, including those being decommissioned, could allow the IAEA to use a greater portion of its effort to conduct other verification activities. Consequently, the National Nuclear Security Administration's Office of International Nuclear Safeguards sponsored this study to evaluate whether there is an opportunity to optimize safeguards approaches for facilities that are shutdown or closed-down. The purpose of this paper is to examine existing safeguards approaches for shutdown and closed-down facilities, including facilities being decommissioned, and to seek to identify whether they may be optimized.

This study begins with definitions for non-operating facilities and a review of design information verification requirements. It then outlines current safeguards approaches and inspection activities by lifecycle phase and outlines potential ways to optimize the safeguards activities being conducted, in particular in-field activities, that could result in reducing the level of safeguards effort required, while maintaining a high degree of assurance that nuclear material (when present) is not diverted and facilities are not misused. The safeguards effort applied in each phase of the facility's life cycle depends strongly on the type of facility. In this study two reference facilities for a State with a comprehensive safeguards agreement and an additional protocol (AP) in force that has a broader conclusion and integrated safeguards applied are considered: a light water reactor and a 100,000 kg separative work unit/year centrifuge enrichment facility.

While this study finds that the measures specified in the IAEA's DIE and DIV guidance should permit the IAEA to implement efficient safeguards at facilities undergoing decommissioning and thus has not identified fundamental changes in the safeguards approaches for shutdown or closed-down facilities, it has identified

¹ "Design Information Examination and Verification Activities" (SG-PR-12261), 2014.

some actions that could reduce safeguards effort (described in chapter 9). In addition, the study has identified the following considerations related to safeguards at shutdown, closed-down and decommissioned facilities.

- Approximately 25% of nuclear facilities under IAEA safeguards are not operating, but have not yet been decommissioned for safeguards purposes.
- The variation in sequence and types of operational activities used for progressing a facility to the status where it is considered decommissioned for safeguards purposes requires the IAEA to develop and implement a facility-specific safeguards approach that is significantly affected by the changes in operational activities and timing for removal of nuclear material from the facility. Streamlined verification measures to reduce inspection effort must be considered with respect to the specific facility as part of a State-level approach.
- The definitions used by the safeguards community for shutdown, closed-down and decommissioned facilities differ from those used by facility operators. The safeguards definitions focus on status of nuclear material and essential equipment, while the operational definitions address production, environmental and safety issues.
- The disposition of equipment from facilities undergoing decommissioning is a weakness in the safeguards system as no legal instrument provides for its monitoring within a country – only the import of AP Annex II equipment or manufacture of Annex I equipment can be verified in a State with an AP in force. This weakness should be addressed through discussions on updating the AP annexes.
- There would be increased opportunities for optimizing safeguards if more precise information was provided by the State on the planned activities at shutdown and closed-down facilities and their expected duration. Although Code 3 of the Subsidiary Arrangements – General Part to the safeguards agreement requires the State to inform the IAEA on any modification of the facility status that can impact safeguards implementation, many States do not inform the IAEA about the expected time duration of an extended shutdown because that information may not have been determined yet by the operator.
- For facilities in a closed-down status, at which (by definition) nuclear material is no longer present, safeguards activities change from an emphasis on nuclear material verification to physical inventory verification (PIV)

performed as part of the DIV to assure the absence of nuclear material (e.g., confirmation of null inventory).

- The effort required to safeguard a facility in the various phases of shutdown and closed-down, including undergoing decommissioning, will be highly dependent on type, size, and status of the non-operating facility; the operator's activities at the facility with respect to nuclear material and timing of removal of nuclear material and essential equipment; and the nuclear fuel cycle of the State. The IAEA's activities should be those necessary to address the identified safeguards objectives as described in the State-level safeguards approach and annual update of the State evaluation report.
- The safeguards effort for a light water reactor would typically decrease from a two-day to a one-day DIV/PIV per year to maintain cognizance of the facility after the facility is shut down and the nuclear material has been removed. Gains in efficiency in implementing safeguards at such a closed down facility could only be made by performing DIV/PIVs on a random, less than annual basis. Such a change might save several tens of person days of inspection per year across all non-operating facilities under safeguards.
- The safeguards effort for a bulk handling facility decreases with removal of nuclear material from the facility. For a centrifuge enrichment plant, the safeguards effort also decreases with removal of centrifuges or rendering them inoperable. Gains in efficiency could be achieved by accelerating these actions.

The study has found that the 2014 IAEA procedure for DIE and DIV¹ provides an effective basis for the IAEA to implement efficient safeguards at non-operating facilities. The effectiveness of safeguards could be enhanced by revision of the Annexes to the Model Additional Protocol (e.g., revising Annex I to require reporting on the location of stored Annex II equipment removed during decommissioning). The efficiency of safeguards could be enhanced by more detailed reporting of operator activities during the non-operating phases and accelerated removal of nuclear material from the non-operating facilities. In addition, guidance to States could be improved through preparation of a new design information questionnaire template for non-operating facilities and a safeguards by design document on the decommissioning process.

3. Introduction

The International Atomic Energy Agency's (IAEA's) effort for safeguarding facilities that are shut down and closed down, including those undergoing decommissioning, is large and growing. Currently about 25% of the facilities under safeguards are not operating. The safeguards concerns for non-operating facilities are initially the same as for operating facilities – diversion of nuclear material and undeclared activities – but decrease as nuclear material and essential equipment are removed. The safeguards activities conducted must also adapt to the changing and non-routine nature of the operator's activities conducted during shutdown and decommissioning. The primary activities associated with this safeguards effort are verifying the storage and reduction of nuclear material inventory and the changes in facility design. With respect to certain facility types, sizes, and operations, the verification effort involved in safeguarding a facility that is closed-down, and which will be or is undergoing decommissioning could be more than for the same facility when it was in routine operation (e.g., typically resulting from more frequent design information verifications (DIVs) to assure removal or destruction of essential equipment and more inspections to verify transfers of nuclear material recovered from hold-up). Such a situation could occur at a centrifuge enrichment plant while the centrifuges are being removed and destroyed or at a plutonium facility while the process system is being dismantled and nuclear material is being recovered and transferred from the facility. As another example, a small research reactor that is not verified annually during operation might need to have a DIV annually during decommissioning while equipment is being removed. A power reactor that averaged one inspection per year may need more than one to verify removal or transfers of nuclear material and equipment.

In order to verify the operational status of a facility, the IAEA conducts the following activities: assessment of all safeguards relevant information; visual observation; examination and analysis of operating records for consistency; environmental sample taking and analysis; application of containment and surveillance (C/S) measures; and assessment of changes in the operational status or modifications to the facility.

The decommissioning process for many facilities may take longer than three years, with nuclear material hold-up and essential equipment and support facilities being removed in different phases. The IAEA's design information examination (DIE) and DIV procedure document¹ provides general guidance for safeguards activities during each operational phase. For shutdown facilities (i.e., before nuclear material is removed), the IAEA applies the same safeguards approach as when the facility was in operation; however, the level of effort changes according to the size of

remaining nuclear material inventories and number of inventory changes to be verified.

The purpose of this paper is to examine existing safeguards approaches for shutdown and closed-down facilities, including facilities being decommissioned. Approaches are outlined to optimize safeguards activities being conducted, in particular in-field activities, that could result in reducing the level of safeguards effort required, while maintaining a high degree of assurance that nuclear material (when present) is not diverted and facilities are not misused. Greater efficiency in safeguarding facilities that are shutdown or closed-down, including being decommissioned, could allow the IAEA to use a greater portion of its effort to conduct other verification activities.²

The paper begins with an examination of the definitions for non-operating facilities and a review of DIV requirements. It then reviews the estimated number of facilities that are subject to IAEA safeguards in each non-operating phase and identifies current verification activities, including DIV objectives, in each lifecycle phase after a facility has become operational. It then examines two reference facilities for a State with a comprehensive safeguards agreement (CSA) and additional protocol (AP) in force that has a broader conclusion and integrated safeguards applied: a light water reactor and a 100,000 kg separative work unit (SWU)/y centrifuge enrichment facility. A light water reactor represents the most common type of facility under safeguards and a centrifuge enrichment plant is a bulk handling facility that has inspections for material accountancy and for detecting facility misuse throughout the year. And finally, the paper concludes with key recommendations for enhancing the effectiveness and efficiency of safeguards.

4. Definitions

In pursuing the current analysis, the operational phases of a facility relevant to this study – shutdown, closed-down, and decommissioned – need to be defined. It is important to recognize that there is a difference in operational phase definitions between the IAEA Department of Safeguards and facility operators. The safeguards definitions address the presence of nuclear material and essential equipment while nuclear safety and nuclear energy definitions address production, safety and environmental issues. For example, the continued presence of nuclear material in storage may not significantly affect the decommissioning schedule of a facility from

² Such a shift of resources could include applying certain inspection resources to a new facility being built in a State from the non-operating facility in the same State.

an operator's perspective, while it is of significant importance for safeguards. Safeguards definitions from the Model Additional Protocol or the IAEA's DIE/DIV procedure are as follows:

Shutdown: a cessation of operations without removal of all nuclear material from the facility.

Temporary shutdown: a facility shut down for a fixed period of time (e.g., weeks to months).

Extended shutdown: a facility shut down for a period longer than one complete material balance period but which is expected to operate again.

Permanent shutdown: a facility officially declared to be taken out of operation permanently.

Closed down: *"an installation ... where operations have been stopped and the nuclear material removed but which has not been decommissioned."*³

State of preservation: major process operations have been stopped, nuclear material inventories have been removed or cleaned out to the extent possible, and decommissioning has not been started.

State of decommissioning: decision to begin decommissioning, and the removal or rendering inoperable of essential equipment has begun.

Decommissioned: *"an installation ... at which residual structures and equipment essential for its use have been removed or rendered inoperable so that it is not used to store and can no longer be used to handle, process or utilize nuclear material."*³

5. Provision and Verification of Design Information

The verification of design information is the primary safeguards activity performed by the IAEA at facilities that are closed down, especially at those facilities undergoing decommissioning. As such, this section provides a detailed review of the requirements in relevant legal instruments for the provision and verification of facility design information.

A State's safeguards agreement and Subsidiary Arrangements-General Part to that agreement establish requirements for the provision and verification of design

³ "Model Protocol Additional to the Agreement(s) between the State(s) and the International Atomic Energy Agency for the Application of Safeguards", INFCIRC/540 (Corrected), 1997.

information. A State is required to provide design information for each of its facilities subject to safeguards in the form of a design information questionnaire (DIQ), which is examined and verified by the IAEA. The State's obligation to provide design information and the IAEA's right to examine and verify that design information extends throughout the entire life cycle of a facility – from construction through final decommissioning.

Relevant provisions in a CSA and Subsidiary Arrangements for providing information on non-operating facilities are as follows:

- INFCIRC/153,⁴ paragraph 45, states: *“The Agreement should stipulate that design information in respect of a modification relevant for safeguards purposes shall be provided for examination sufficiently in advance for the safeguards procedures to be adjusted when necessary.”*
- The model Subsidiary Arrangements – General Part require:
 - Code 3.1.6. *“Provision of information on proposed significant changes to data previously provided ... [as] soon as the decision to modify the facility has been taken”;*
 - Code 3.1.7. *“Provision of information on significant changes to data previously provided ... based on as-built data ... [as] soon as possible after completion of significant changes;*
 - Code 3.1.8. *“Provision of information on changes to data previously provided ... other than changes specified in Code 3.1.6. ... Together with the first inventory change report made after the modification is completed.”*

To comply with these requirements, the State provides to the IAEA a revised DIQ for the facility containing specific facility design and operating information. There are presently ten DIQ templates: nuclear material outside facilities; research and development facilities; conversion and/or fuel fabrication plants; isotope enrichment plants; critical and sub-critical facilities; research and power reactors; reprocessing plants; separate storage installations; spent fuel encapsulation plants; and geological repositories. These DIQs are primarily designed to collect information on facilities in the construction and operating phases.

⁴ “The Structure and Content of Agreements between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons”, INFCIRC/153 (Corrected), 1972.

Provisions for IAEA verification of changes in status of the facility in relation to the re-examination and verification of the facility design information are as follows:

- INFCIRC/153, Paragraph 47 states: *“The Agreement should provide that design information shall be re-examined in the light of changes in operating conditions....”*
- Board of Governors decision, GOV/2554/Attachment 2/Rev 2 (1 April 1992), states *“Under comprehensive safeguards agreements, the Agency’s authority to verify design information is a continuing right which does not expire when a facility goes into operation; nor does this continuing right expire with the closing down of a facility. Visits by Agency inspectors to verify that facilities which have been closed down remain in their closed-down condition are part of design verification and provide assurance that such facilities are not re-activated and used for undeclared activities.”*

Further clarification for States on these obligations and the Agency’s rights and activities are provided in several IAEA guidance documents published in the IAEA Services Series.

- IAEA Services Series 21, *Guidance for States Implementing Comprehensive Safeguards Agreements and Additional Protocols*
 - Section 5.1, page 24: *“The IAEA’s right to examine and verify design information extends throughout the life cycle of the facility – from before construction through to final decommissioning.”*
 - Section 5.2, page 26: *“Facility design changes, or changes in the way operations at facilities are conducted, must be evaluated by the IAEA to determine the effect on the safeguards approach. The IAEA may need to make changes to its safeguards measures, which could involve such activities as installing equipment, or relocating cameras. Therefore, this information must be provided to the IAEA well in advance of making the change, specifically, ‘as soon as the decision to modify the facility has been taken’.”*
- IAEA Services Series 30, *Safeguards Implementation Guide on Facilitating IAEA Verification Activities*
 - Annex II describes the life cycle or operational phases of a facility and associated safeguards activities, and the kinds of information that should be provided by the State to the IAEA at each phase.

6. Estimated Number of Non-operating Facilities

Because information on the exact number and type of nuclear facilities under safeguards in the different non-operating phases has not been compiled by the IAEA and the raw data is not available outside the IAEA Department of Safeguards (because the Department of Safeguards databases containing the information also contain related information classified as Safeguards Confidential), information from the IAEA Department of Nuclear Energy databases presented in 2016 on the NUCLEUS website was used to estimate the number of non-operating facilities that exist around the world. These databases only provide information on the number of facilities in non-operating status, but do not enable a determination of those facilities that meet the safeguards definition of ‘closed-down’. Some facilities listed as ‘decommissioning’ in the Department of Nuclear Energy databases may still contain nuclear material inventories and would be identified as ‘shutdown’ for safeguards purposes. Other facilities listed in the databases as ‘decommissioning’ may have met the definition of ‘decommissioned for safeguards purposes’, if the nuclear material has been removed and sufficient essential equipment has been rendered inoperable or removed.

Information on the status of nuclear facilities was drawn from the following Department of Nuclear Energy databases: Power Reactor Information System Database, Research Reactor Database, and Nuclear Fuel Cycle Information System Database. The Department of Nuclear Energy in each of the databases and the Department of Safeguards in its DIE and DIV procedure use different terms for the phases of non-operating status. The Department of Nuclear Energy databases are focused on production, safety and environmental issues, while the Department of Safeguards focuses on presence of nuclear material and essential equipment. The Department of Nuclear Energy databases provide no information as to the presence or quantities of nuclear material remaining at the non-operating facilities.

The Power Reactor Information System Database lists 2 power reactors in non-nuclear weapon states (NNWS) that are in long-term shutdown and 157 power reactors that have been permanently shut down (77 in NNWS and 80 in nuclear weapon states (NWS)). The Research Reactor Database lists 1 research reactor in a NWS in extended shutdown, 133 research reactors in permanent shutdown (50 in NNWS and 83 in NWS), and 352 decommissioned research reactors (100 in NNWS and 252 in NWS). The Nuclear Fuel Cycle Information System Database lists 11 nuclear facilities in standby (6 in NNWS and 5 in NWS), 36 facilities shutdown (19 in NNWS and 17 in NWS), 49 facilities in decommissioning (16 in NNWS and 33 in NWS), and 56 facilities decommissioned (26 in NNWS and 30 in NWS). Table 1 summarizes the number of facilities in NNWS in non-operating status based on

these databases. From these data it can be estimated that there are approximately 170 non-operating nuclear facilities under IAEA safeguards.

Table 1. Non-operating facilities in non-nuclear weapon states⁵

Facility type	Shutdown	Decommissioning	Decommissioned
Conversion ¹	6	1	1
Enrichment ¹	4	2	5
Fuel fabrication ¹	6	1	12
Research reactor ²	51	-	100
Power reactor ³	79	-	-
Spent fuel storage ¹	3	2	1
Reprocessing and recycling ¹	4	10	7
Spent fuel conditioning ¹	2	0	0
Total	155	16	126

¹ Nuclear Fuel Cycle Information System Database

² Research Reactor Database

³ Power Reactor Information System Database

7. Overview of Verification Activities

In order to examine the possibility of optimizing safeguards activities in shutdown and closed-down phases, it is essential to examine the current verification practices not only in these phases, but also how they compare to safeguards activities in the operational phase. This section provides an overview of existing verification activities at facilities that are shut down, closed-down, and decommissioned.

7.1 Shutdown

A nuclear facility can be shut down for many reasons, including: process system or building maintenance; process system modifications; repairs to structures, systems,

⁵ Data compiled from State-by State data in 2016 IAEA databases located on the NUCLEUS website. 'Closed down – state of decommissioning' in this text is equivalent to 'decommissioning' in the table. Facilities considered to be 'Closed down – state of preservation' in this text would be included under 'shutdown' in this table. 'Shutdown' in this table includes 'standby', 'extended shutdown', 'long-term shutdown', and 'permanently shutdown' in the databases.

or components; remediation of technical problems; regulatory or public concerns; security events, including local conflicts or wars; political decisions; or lack of resources. During shutdown, nuclear material may be transferred from process to storage locations within the facility and shipments of nuclear material from the facility may be occurring.

A facility shutdown can be scheduled (e.g., power reactor reloading) or unplanned (e.g., power reactor incident or accident). A shutdown may be operationally subcategorized as temporary, extended, or permanent. A temporary shutdown may occur for routine maintenance or for a physical inventory taking, and is generally for a fixed period of time (e.g., weeks to months). During a 'temporary shutdown', it may be found that re-starting production operations has to be postponed without a firm restart schedule, but with the intention to restart the facility eventually; the facility is then in 'extended shutdown' (also known as standby, long-term shutdown, or suspended operation). When a facility is officially declared to be taken out of operation permanently it is operationally described as being in 'permanent shutdown'. When all of its nuclear material has been removed, the facility is considered to be 'closed-down' for safeguards purposes.

Shutdown nuclear facilities have an inventory of nuclear material. During this phase, the IAEA continues to apply the same safeguards approach as when the facility was under normal operation to verify that the nuclear material has not been diverted. The IAEA conducts interim inspections to verify nuclear material transfers from the facility. Periodic PIV and DIV activities continue to be conducted to assure the continued presence of the declared nuclear material, that the declared facility design is still valid, and that the plant is not being misused for non-peaceful nuclear purposes. The inventory of some nuclear material strata may become zero during the shutdown period, and thus no further verification of the strata would be required. DIVs, PIVs, interim inspections, and complementary accesses (CAs, for countries with an AP in force) are performed as stated in the annual implementation plan (AIP) for the State.

Code 3 of the Subsidiary Arrangements – General Part to the safeguards agreement requires the State to inform the IAEA on any modification of the facility status that can impact safeguards implementation and specifies the timeliness for providing the information. Many States do not inform the IAEA about the expected time duration of an extended shutdown because this may be unknown when the shutdown occurs. For many reasons, the facility operator may not yet have determined how long its facility will be out of operation or if the facility will be returned to operation. For example, the facility may be shut down for economic or political reasons, such that when the conditions change, the facility may be restarted. The time and cost to

make repairs may also take time to understand, especially as regulations may be changing because of relevant events (e.g., shutdown of reactors in Japan following Fukushima earthquake and tsunami).

7.2 Closed-down: state of preservation

A closed-down facility in a 'state of preservation' remains capable of receiving nuclear material and re-starting operation. Facilities in a 'state of preservation' continue to be categorized as a nuclear facility under safeguards. Normally the State informs the IAEA, as provided for in the subsidiary arrangements, that the facility status will change, and that the nuclear material has been removed from the facility. The IAEA would conduct a PIV at the end of the material balance period to confirm that the declared nuclear material inventory is or remains zero. The facility operator is required to continue providing to the IAEA 'null' physical inventory lists (PILs) and material balance reports (MBRs) even when the facility has a zero inventory. Annual PIVs, DIVs, and random CAs (for countries with an AP in force) are performed as identified in the AIP. Interim inspections no longer occur. Item facilities, such as power or research reactors, would have shipped the nuclear material (e.g., spent fuel assemblies) to another reactor facility or an irradiated fuel storage facility, and inspectors can easily verify that the facility inventory is zero. Bulk handling facilities will retain some difficult-to-remove residual nuclear material in process equipment and piping or ductwork as hold-up material. The quantity of nuclear material in hold up typically will have been removed from the accounting books as 'material unaccounted for' or is carried on the books as an estimated quantity. The amount of holdup material is typically quantified during the decommissioning phase when the equipment is dismantled and the nuclear material can be accessed.

7.3 Closed-down: state of decommissioning

In general, there are three operational phases of decommissioning: (1) initial activities, (2) major decommissioning and storage, and (3) license termination. 'Initial activities' encompass a certification of permanent cessation of operation to the State Regulatory Authority, and the preparation of a decommissioning report, which provides a description of the planned decommissioning activities, a schedule for accomplishing them, and an estimate of the expected costs. 'Major decommissioning and storage' activities include facility clean up, removal of major components (e.g., in power reactors: the reactor vessel, steam generators, large piping systems, pumps, and valves), and storage or disposal of those components. 'License termination' activities include preparation and submittal of the site remediation plans necessary to get the operating license terminated. From the IAEA

safeguards perspective, only the ‘major decommissioning and storage’ activities will have an impact on safeguards implementation.

The IAEA’s DIE and DIV procedure¹ provides guidance for implementing safeguards during decommissioning. States should inform the IAEA in advance of the start of decommissioning about the facility’s decommissioning plan. This plan should detail the time schedule for removing or rendering inoperable the essential equipment of the facility. The IAEA legal instruments (e.g., safeguards agreement, AP, and subsidiary arrangements) do not establish a requirement for a State to provide the IAEA with information about the places within a State where the removed major equipment or components will be transferred. The absence of this information could be significant with respect to sensitive equipment that could be used to build an undeclared facility.

A customized safeguards approach for a facility undergoing decommissioning may be provided in a DIV Plan developed for the facility.⁶ The IAEA verifies the decommissioning process through inspections, DIVs, and CAs (if an AP is in force) throughout the decommissioning phase. Installed IAEA equipment will be removed, as appropriate. Hold-up nuclear material recovered from equipment or residing in equipment transferred to waste would be verified during inspections before the nuclear material is transferred from the facility. Hold-up material that cannot be removed from equipment may be difficult to measure and an appropriate non-destructive assay measurement method would be used.

During the decommissioning period, the IAEA assesses periodically the level of effort required to reactivate the facility with the remaining equipment.

7.4 Decommissioned

In practice, ‘decommissioned’ does not mean that all of the essential equipment has been removed, but rather that sufficient equipment has been removed or rendered inoperable so that it would require at least as much effort and resources to refurbish and restart the facility as to build a new one. As noted above, the IAEA’s legal instruments do not require reporting on, or authorize the IAEA to verify, where

⁶ A DIV Plan used to be required by the Department of Safeguards for all facilities, but was determined to be unnecessary for facilities for which the measures can be readily added to the State-level approach and annual implementation plan. DIV plans remain useful for more complicated or unique facilities. IAEA use of the plans is still evolving. While the plans are valuable for certain facilities, such as in Japan and Republic of Korea, they do not bring much value for States with small nuclear programs.

removed structures and equipment have been transferred within a State.⁷ In the case of the Ningyo Toge centrifuge enrichment plant in Japan, which is undergoing decommissioning, an IAEA procedure to follow up the removal and to observe the on-site destruction of the equipment was agreed to with Japan and is being implemented.⁸

After the IAEA has made a determination that sufficient residual essential equipment has been removed or rendered inoperable so that the facility can no longer be used to store or handle, process, or utilize nuclear material, and that the efforts and resources to reactivate the facility are equal to or exceed that necessary for a new facility, the IAEA will confirm to the State that the facility has been ‘decommissioned for safeguards purposes’ and removed from the list of facilities subject to safeguards. After this time, for countries with an AP in force, the only verification activity that can be performed at the decommissioned facility are CAs to confirm the continued decommissioned status. For CSA-only States, no further verification activity is performed.

7.5 Transitioning Between Phases

The process of a facility moving from shutdown, to closed-down, to decommissioned may not be straight forward. Some facilities continue operations in some areas of the facility (e.g., storage and waste recovery areas) after other areas have been declared as shutdown, closed-down, or decommissioned. At some reactor facilities, the spent fuel remains in storage at the facility after reactor areas have been decommissioned. In at least one research reactor under safeguards, the core and nuclear material in the core have been left in place to permit decay of fission and activation products while equipment and parts of the building are being removed.

The sequence of shutting down and decommissioning activities is typically determined by the situation and history of the facility. These variations were confirmed during the IAEA’s multi-Member State Support Program project (SP-1 04PSS-01, “Determination of Decommissioned Status of Facilities”) that sought

⁷ There is no legal requirement for a State to report on a location where essential equipment is moved within the State, except as a voluntary declaration. The IAEA would have to establish a question or inconsistency with respect to the location to request access under AP, Article 5.(c) or the State could offer access to the location under AP, Article 8. If another State has reported that the equipment was shipped to the State, under AP Article 2.a.(ix), the IAEA may request access to its location under Article 5.(b). It is unknown to the authors as to why information on the location of Annex II equipment removed from a facility was not included in the AP.

⁸ Under the Iran-P5+1 Joint Comprehensive Plan of Action, the IAEA also maintains cognizance over the centrifuges removed from cascades. The authors are not aware of any other cases where the IAEA has followed equipment under routine CSA safeguards implementation.

information on decommissioning for a variety of facility types in several States (i.e., Canada, Germany, Japan, Spain, U.K., and the U.S.). Using the results of this project, an internal study within the Department of Safeguards was conducted that analyzed the sequences of activities that facilities may go through from being shut down through being decommissioned and identified safeguards measures for each phase.⁹ In 2014, the Department of Safeguards approved a new internal DIE and DIV procedure document¹ that described relevant design verification measures to be undertaken during all phases of a facility's life cycle.

The State is required to provide updates to the DIQ for changes in the operating status of the facility until the facility has been determined to be decommissioned by the IAEA. The DIQ templates for facility types require reporting on the status of the facility and its routine operations, and for a bulk handling facility, the design capacity and the anticipated throughput of the facility. In addition, the State should inform the IAEA on the change of operating status, as required by the facility attachment, through an operational report (or 'concise note'). There is no standard model for the information in concise notes reporting changes of operating status.

8. Design Information Verification Activities

DIE and DIV are activities carried out by the IAEA to verify the correctness and completeness of the design information provided by the State on a nuclear facility. These activities are carried out throughout each facility lifecycle phase to confirm the continued validity of the design information and the safeguards approach.

When changes in design information are reported, such changes are examined and may be verified to establish whether the changes have safeguards implication. During the initial facility DIE, the IAEA prepares a list of equipment, systems, and structures that are essential for the declared operation of the facility – the Essential Equipment List (EEL). The EEL identifies items that may influence the facility's operational status, function, capabilities and inventory.

DIVs performed during the construction and commissioning phases of facilities provide assurance that the facilities or parts of facilities are being built as declared

⁹ This study was performed by the Concepts and Approaches Section beginning in 2009. However, information could not be obtained regarding the final results of the study. The preliminary results of the study identified that there were many variations in decommissioning processes and that IAEA safeguards would need to be flexible to address this variability. Information was also not available to determine if the results of the study were used by SGOB (as process owner) in developing the DIE/DIV procedure. The new procedure revised past guidance with respect to the State-level concept and provides the necessary flexibility.

and confirm the as-built design. DIVs performed at operating, shutdown, and closed-down facilities confirm that undeclared changes have not been made to the facility design and that the facility operates as declared. Table 2 presents the main objectives of DIVs according to the facility lifecycle phase for operational through decommissioned status. The status of equipment on the EEL is updated based on the results of periodic DIVs and updated DIQs.

The verification of the removal or rendering inoperable of essential equipment is used for establishing and confirming the decommissioned status of a facility for safeguards purposes. Aspects considered when assessing equipment for decommissioning, include:

- the essential nature of the equipment, system or structure to the facility's function;
- commercial availability;
- complexity of modification, re-installation or repair;
- time required for modification, re-installation or repair; and
- the detection likelihood of modification, re-installation or repair.

'Decommissioned for safeguards purposes' applies to a facility at which residual structures and equipment essential for its operation have been removed or rendered inoperable so that it is not used to store and can no longer be used to handle, process or utilize nuclear material. In practice, this does not mean that all of the essential equipment has to be removed or rendered inoperable, but sufficient equipment has been removed or destroyed so that it would cost more to refurbish the facility than to build a new one.

Periodic DIE and DIV performed during decommissioning provide information on the status of removal or rendering inoperable of the declared essential equipment. The final DIE and DIV activities are conducted by the IAEA to enable an IAEA management decision that the facility has been decommissioned as reported by the State. Because of differences in decommissioning processes, this decision must be made by expert judgement for each facility as to when sufficient essential equipment has been removed or rendered inoperable. Once the IAEA is able to determine that the facility can no longer be used for its declared purpose, the facility is declared to be decommissioned for safeguards purposes and the IAEA formally informs the State of its conclusion.

The IAEA's right to perform DIV activities terminates after the IAEA has concluded, and informed the State, that the facility is 'decommissioned for safeguards

purposes'. However, further IAEA access is possible through the AP (if in force), specifically through complementary access (Article 5.a.(iii)).

Table 2. Design information verification objectives by lifecycle phase after the facility has become operational¹

Operational	Shutdown	Closed-down: preservation	Closed-down: decommissioning	Decommissioned
Assure correctness, completeness, consistency and timeliness of design information	Assure correctness, completeness, consistency and timeliness of design information	Assure correctness, completeness, consistency and timeliness of design information	Assure correctness, completeness, consistency and timeliness of design information	Confirm that the facility has been decommissioned for safeguards purposes
Assure absence of undeclared operations	Assure absence of undeclared operations	Assure absence of undeclared operations	Assure absence of undeclared operations	
Establish, update, and store design information records and photographs	Establish, update, and store design information records and photographs	Establish, update, and store design information records and photographs	Establish, update, and store design information records and photographs	
Assure no undeclared safeguards relevant design or operational changes.	Assure no undeclared safeguards relevant design changes	Assure no undeclared safeguards relevant design changes	Assure no undeclared safeguards relevant design changes	
Assess if the utility and support design is appropriate for the declared function and capability	Verify the declared shutdown status and operations related to the transfer of nuclear material	Verify the declared closed-down status – preservation state – and verify absence of nuclear material other than residual holdup.	Verify the declared closed-down status – decommissioning state – and verify the removal of residual holdup and transfers, including waste.	
Assess the adequacy of the IAEA safeguards approach	Assure the integrity of containment and its adequacy	Assure the integrity of containment and its adequacy	Evaluate the Essential Equipment List with respect to the need for removal or rendering inoperable and assess the effort for reactivation of the facility	
Assure appropriateness of the installation and use of containment and surveillance (C/S) measures	Assure appropriateness of the installation and use of containment and surveillance (C/S) measures	Assure appropriateness of the installation and use of containment and surveillance (C/S) measures	Assure the appropriateness of selected C/S measures	
Assure appropriateness of nuclear material flow and inventory verification methods	Assure appropriateness of nuclear material flow and inventory verification methods		Assure the removal and/or rendering inoperable of essential equipment	
Assure appropriateness and correctness of accounting and operating records				
Assure appropriateness of accounting and				

9. Estimate of Current In-field Safeguards Activities and Effort in each Phase

The safeguards effort applied in each phase of the facility's life cycle depends strongly on the type of facility. In this study we will consider two reference facilities for a State with a CSA and AP in force that has a broader conclusion and integrated safeguards applied: a light water reactor and a 100,000 kg SWU/y centrifuge enrichment facility. As noted previously, a light water reactor represents the most common type of facility under safeguards and a centrifuge enrichment plant is a bulk handling facility that has inspections for material accountancy and for detecting facility misuse throughout the year. The safeguards issues associated with most other facility types are covered by these two facility types.

9.1 Light Water Reactor

The general approach to safeguarding a light water reactor in each operational phase is described in Table 3. Table 4 summarizes the safeguards effort applied on average to a light water reactor under integrated safeguards in terms of number of inspections, DIVs, and CAs performed in a year in which the reactor was identified for an interim inspection and a CA in the AIP.¹⁰ One inspector is assumed for each inspection, DIV, and CA. The safeguards effort for a light water reactor would typically decrease from a two-day to a one-day DIV/PIV per year to maintain cognizance of the facility after the facility is shut down and the nuclear material has been removed.¹¹ Gains in efficiency in implementing safeguards at such a facility could be made by performing DIV/PIVs on a random, less than annual basis. Such a change might save several tens of person days of inspection per year across all non-operating facilities under safeguards. For example, if 50% of the 79 non-operating power reactors in non-nuclear weapon States have had all nuclear material removed and 20% of these reactors were randomly selected for inspection each year, there would be a savings of 32 PDI per year.

¹⁰ The reactor would have a 20% likelihood of selection for an interim inspection and would typically only be selected for a CA if there was a question related to power reactors in the State.

¹¹ The reduction depends on how the shutting down of the reactor is being conducted by the operator. There is significant variability in operator processes being followed because of circumstances requiring the reactor to be shut down. For some operating reactors, the inspection effort is already only one day.

9.2 Centrifuge Enrichment Facility (100,000 kg SWU/y)

The general approach to safeguarding a centrifuge enrichment facility in each operational phase is described in Table 5. Table 6 shows the safeguards effort applied for a small centrifuge enrichment facility under integrated safeguards in terms of number of inspections, DIVs, and CAs performed per year. These figures are related to a centrifuge enrichment plant that was identified for a CA in the AIP. Two inspectors are assumed for each non-PIV inspection, DIV, and CA. The effort required to safeguard such a facility will be highly dependent on the operator's activities at the facility with respect to nuclear material and timing of removal of essential equipment. The activities will be facility specific to address the identified safeguards needs as described in the State evaluation report and State-level approach.

Table 3. Light water reactor safeguards for each operational phase

	Operating	Shutdown	Closed down – preservation	Closed down – decommissioning	Decommissioned
Description	Fresh fuel is received on an annual basis and placed in storage for the next refueling. During refueling, irradiated fuel is removed from the core and transferred to the spent fuel pond. After refueling, the reactor head is sealed. In some light water reactors, cooled irradiated fuel is removed from the spent fuel pond and transferred to a dry storage installation that may be a part of the facility or a facility unto itself.	The reactor possesses fresh and/or irradiated fuel. For a planned extended shutdown, all irradiated fuel may be moved to the spent fuel pond such that the reactor core is empty. If the reactor is being prepared for being closed down, shipments of fresh fuel and irradiated fuel to other facilities may be occurring.	The facility possesses no fresh or irradiated fuel. No decommissioning work has been initiated; only necessary maintenance work is performed.	The facility possesses no fresh or irradiated fuel. Decommissioning work is underway with removal or destruction of essential equipment according to the decommissioning plan.	Sufficient essential equipment removed or disabled to prevent future operation of facility without great effort
Diversion scenarios	(1) removal of fresh fuel assembly or pins from the storage area or during transfer to reactor core; (2) removal of irradiated fuel assembly or pins from reactor core or during transfer from reactor core; and	(1) removal of fresh fuel assembly or pins from storage area; (2) removal of irradiated fuel assembly or pins from reactor core or during transfer from reactor core; and (3) removal of irradiated	none, no declared nuclear material present at facility.	none, no declared nuclear material present at facility	none, no declared nuclear material present at facility

	(3) removal of irradiated fuel assembly or pins from spent fuel pool or during transfer to cask for storage or shipment.	fuel assembly or pins from spent fuel pool or during transfer to cask for storage or shipment.			
Misuse scenarios	(1) irradiation of undeclared nuclear material in the reactor core to produce plutonium or U-233 for recovery elsewhere.	(1) irradiation of undeclared nuclear material in the reactor core to produce plutonium or U-233 for recovery elsewhere.	(1) refueling and restart of reactor with undeclared fuel, (2) irradiation of undeclared nuclear material in the reactor core to produce plutonium or U-233 for recovery elsewhere.	(1) replacement of damaged or removed essential equipment, (2) refueling and restart of reactor with undeclared fuel, (3) irradiation of undeclared nuclear material in the reactor core to produce plutonium or U-233 for recovery elsewhere	none, misuse of facility is no longer credible
Information submitted	(1) updated DIQ; (2) inventory change reports (ICRs), PIL and MBR; (3) operating schedule, including planned shutdown for refueling; (4) schedule of shipments and receipts.	(1) updated DIQ, (2) ICRs, PIL and MBR; (3) operating schedule (transfers from core and shipments from facility); (4) schedule of shipments.	(1) updated DIQ, (2) PIL and MBR, (3) operating schedule (major maintenance activities affecting safeguards implementation).	(1) updated DIQ, (2) PIL and MBR, (3) operating schedule (decommissioning activities and removal/destruction of essential equipment)	none, reactor is no longer considered a nuclear facility for safeguards purposes.
Principal safeguards measures	(1) annual PIV and DIV, (2) random interim inspection (one inspection per year per five reactors),	(1) annual PIV and DIV, (2) random interim inspection (one inspection per year per five reactors),	(1) annual DIV with PIV, and (2) possible CAs	(1) annual DIV with PIV, (2) additional DIVs may be required to verify removal or destruction of essential equipment, and	(1) possible CA

	(3) inspections as required to confirm fresh fuel receipts and irradiated fuel cask loading and transfer, and (4) possible CAs.	(3) inspections as required to confirm irradiated fuel cask loading and transfer, and (4) possible CAs.		(3) possible CAs	
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Table 4: Current safeguards effort (person days of inspection (PDI)/y) for a light water reactor under integrated safeguards

Safeguards Activity	Operational	Shutdown	Closed-down: preservation	Closed-down: decommissioning	Decommissioned
PIV	1	0.5	-	-	0
Interim Inspection	1	1	0	0	0
DIV	1*	0.5*	1*	1 – 2*,**	0
CA	1	1	1	1	1
Total	4	3	2	2-3	1

*Assuming no changes in design information affecting safeguards implementation submitted during the year. DIV and PIV performed during same inspection. The smallest assigned effort for an inspection is one PDI, without regard to whether the inspection takes one hour or a full day in the facility.

**Depending on the rate of decommissioning of the facility and changes in safeguards significant design information.

Table 5. Centrifuge enrichment plant safeguards for each operational phase

	Operating	Shutdown	Closed down - preservation	Closed down - decommissioning	Decommissioned
Description	The facility receives natural uranium UF ₆ feed cylinders, enriches uranium to low enriched uranium (LEU), ships LEU in UF ₆ product cylinders, and stores depleted uranium in UF ₆ tails cylinders. Small quantities of waste are generated through chemical traps and maintenance activities.	The facility possesses feed, product, and tails UF ₆ in cylinders, uranium scrap, and waste nuclear material. For a planned extended shutdown, nuclear material in the process system may be transferred to cylinders and all items containing nuclear material placed in storage. Centrifuges in cascades would continue to operate in recycle mode or on vacuum.	The facility possesses no nuclear material, except contamination in piping, equipment, and chemical traps. Centrifuges are stopped and cascades and process system brought to atmospheric pressure using dry air.	The facility possesses no nuclear material, except contamination in piping, equipment, and chemical traps. Decommissioning work is underway with removal or destruction of essential equipment according to the decommissioning plan. The cascades and process system are no longer isolated and are open to moist air.	Sufficient essential equipment removed or disabled to prevent future operation of facility without great effort.
Diversion scenarios	(1) undeclared removal of LEU product, natural uranium, or depleted uranium from process or from cylinders, (2) undeclared removal of nuclear material in waste.	(1) undeclared removal of LEU product natural and depleted uranium from process or from cylinders, (2) undeclared removal of nuclear material in waste.	none, no declared nuclear material present at facility, except small quantities of hold-up in process piping, centrifuges, and chemical traps.	none, no declared nuclear material present at facility, except small quantities of hold-up in process piping, centrifuges, and chemical traps.	none, no declared nuclear material present at facility.
Misuse scenarios	(1) production of higher levels of enriched uranium (especially high	(1) production of higher levels of enriched uranium (especially HEU)	(1) return process system and cascades to vacuum, (2) restart centrifuges,	(1) return process system and cascades to vacuum, (2) restart centrifuges,	none, misuse of facility is no longer credible.

	enriched uranium (HEU)) through cascade reconfiguration or refeeding product, (2) excess production of LEU product.	through cascade reconfiguration or refeeding product, (2) excess production of LEU.	(3) produce product, (4) produce higher levels of enriched uranium (especially HEU) through cascade reconfiguration or refeeding product.	(3) produce product, (4) produce higher levels of enriched uranium (especially HEU) through cascade reconfiguration or refeeding product.	
Information submitted	(1) updated DIQ; (2) ICR, PIL, MBR; (3) operating schedule; (4) schedule of shipment and receipts.	(1) updated DIQ; (2) ICR, PIL, MBR; (3) operating schedule; (4) schedule of shipments.	(1) updated DIQ; (2) PIL, MBR; (3) operating schedule (major maintenance activities affecting safeguards implementation).	(1) updated DIQ; (2) ICR, PIL, MBR; (3) operating schedule (decommissioning activities and removal/ destruction of essential equipment).	none, centrifuge enrichment plant is no longer considered a nuclear facility for safeguards purposes.
Principal safeguards measures:	(1) annual PIV and DIV; (2) random interim verification to confirm nuclear material flows; (3) limited frequency unannounced access (LFUA) inspections, and (4) possible CA.	(1) annual PIV and DIV; (2) random interim verification to confirm nuclear material flows; (3) LFUA inspections, and (4) possible CA.	(1) annual DIV with PIV; (2) LFUA inspections, and (3) possible CA.	(1) annual DIV with PIV; (2) interim inventory inspection to verify shipments of waste; (3) LFUA inspection, and (4) possible CA.	(1) possible CA.

Table 6: Estimated current safeguards effort (PDI/y) for a 100,000 kg SWU/y centrifuge enrichment plant under integrated safeguards

Safeguards Activity	Operational	Extended shutdown	Closed-down: preservation	Closed-down: decommissioning	Decommissioned
PIV	10	6	1	1	0

Interim Inspections	10	10	0	0-2*	0
LFUA	12	12	6	2	0
DIV	2**	2**	1**	1-7***	0
CA	2	2	2	2	2
Total	36	32	10	6-16	2

*Interim inspection may be required to verify transfers of containers with recovered hold-up nuclear material or wastes.

**Assuming no changes in design information affecting safeguards implementation submitted during the year. DIV and PIV performed during same inspection.

***Depending on the rate of decommissioning of the facility and changes in safeguards significant design information.

10. Summary of New Approach Options (General and Facility Specific)

Enhancements to the effectiveness and efficiency of safeguards implementation at shutdown and closed-down facilities should be considered within the IAEA's State-level concept for safeguards implementation and the safeguards objectives therein. The IAEA's State-level safeguards objectives relevant at the nuclear facility level are the detection of diversion of declared nuclear material and the detection of misuse of the nuclear facility. Both objectives are relevant for operating and shutdown facilities (i.e., facilities with nuclear material). For a closed-down facility, at which all nuclear material except holdup has been removed, only the second objective remains relevant. For a facility that has been determined to be decommissioned for safeguards purposes, neither objective is relevant. CAs to the decommissioned facility provide assurance that an undeclared, new nuclear capability is not being re-established at the location, thus addressing the state-level safeguards objective of detecting undeclared nuclear material or activities in the State as a whole.¹²

Facility-specific safeguards objectives, safeguards measures, and the intensity of application of the measures are identified in the State-level safeguards approach for a State. The measures to be implemented during a given year are specified in the AIP for that year taking into consideration the findings and recommendations in the State Evaluation Report. The primary factors affecting the safeguards measures and their implementation are the quantity and locations of nuclear material and the status of essential equipment. Potential gains in efficiency in the safeguards approach need to consider potential changes to how the State defines and operates the facility and enhancements to how the IAEA meets its objectives.

The following subsections provide recommendations for potential enhancements to the effectiveness and efficiency of safeguards implementation. Some of the recommendations are based on best practices already being implemented by the IAEA for some non-operating facilities. Because IAEA safeguards is still evolving under the State-level concept, safeguards implementation is not yet consistent across all Sections and Divisions.¹³ Additionally, facility officers must make a decision as to what is practical and efficient for their facilities. The analysis below is

¹² Although the number of CAs at decommissioned facilities is no longer reported in the IAEA's Safeguards Implementation Report, the authors believe that the IAEA continues to conduct one to three such CAs per year.

¹³ The IAEA updated its DIE/DIV procedure¹ with respect to the State-level concept in 2014 to enable finding greater efficiencies. A State Evaluation Group's ability to identify efficiencies when preparing the safeguards approach is dependent on the creativity of the group.

focused on two specific facility types (a nuclear power reactor and centrifuge enrichment plant), though it may provide broader insights for other item and bulk processing facilities.

10.1 Shutdown

- **Item facility** - nuclear power reactor: No change in the safeguards approach is recommended when an item facility is shut down because of the low-level of effort required to restart the facility. For example, restart of a reactor would be similar in effort to a refueling campaign. IAEA discussions with the State should be held regarding moving irradiated fuel from the reactor core to the storage pool, to facilitate future inventory verification effort. The core should be verified and sealed. If the facility is to transition to a closed-down facility and if the nuclear material is not to be shipped to a different facility, the storage area could be declared as a facility separate from the remainder of the facility (especially if the spent fuel has been moved to dry storage) to permit the reactor area to be declared as a closed-down facility. This would permit a reactor to be safeguarded as a storage facility and a closed-down reactor instead of as a shutdown reactor. The reactor site could be periodically observed using thermal imaging from a satellite to confirm the reactor has not resumed operation. Such observation could reduce the number of DIVs and CAs needed to maintain assurance of reactor shutdown.
- **Bulk processing facility** - centrifuge enrichment plant: No change in the safeguards approach is recommended when a bulk processing facility is shut down. For a centrifuge enrichment plant, because the centrifuges remain spinning and the cascades remain under vacuum, enrichment operations could be resumed in under a day. IAEA discussions with the State should be held regarding drawing the centrifuge enrichment plant process system to vacuum and moving all cylinders to the storage area to facilitate future inventory verification effort. Feed and withdrawal chests could be sealed. Items could be sealed to facilitate reverification at future PIVs and for cylinder shipments. If the facility is to transition to a closed-down facility and if the nuclear material is not to be shipped to a different facility, the storage area could be declared as a facility separate from the remainder of the facility to permit the process area to be declared as a closed-down facility. LFUAs at the enrichment plant should continue at the same frequency as when the plant was under routine operation.

10.2 Closed-down: state of preservation

- **Item facility** - nuclear power reactor: After removal of all nuclear material from the facility, the primary safeguards activity will involve verification that the reactor core remains unopened through verification of seals. Only an annual DIV is necessary to verify that there are no changes to the facility and that the seals on the core remain intact. To support use of less frequent or random DIVs, the reactor site could be randomly observed using thermal imaging from a satellite to confirm the reactor has not resumed operation.
- **Bulk processing facility** - centrifuge enrichment plant: Restart of the centrifuges in a cascade would be equivalent to bringing an installed new cascade on-line and some cascades could be brought back into operation in less than one month. After removal of all nuclear material from the facility, except for residual holdup in the process equipment, piping, and chemical traps, an annual DIV and LFUAs should be performed to verify that the centrifuges remain shut down. Environmental sampling activities should continue to look for changes from the facility baseline. Remotely accessed power or electromagnetic frequency monitors could be used to verify that power is not being provided to the centrifuges in the cascades and to support use of random DIVs and less frequent LFUAs.

10.3 Closed-down: state of decommissioning

- **Item facility** - nuclear power reactor: Until removal of the core, the primary safeguards activity will involve verification that the reactor core remains unopened through verification of seals. The facility could be requested to voluntarily report where intact equipment listed in Annex II of the AP (e.g., primary coolant pumps) are being moved (with the IAEA using AP Article 8, Article 5(b) for equipment or materials confirmed by the State as imported under Article 2.a.(ix), or Article 5(c) for access to confirm the information). DIVs should be performed as necessary to verify that other essential equipment was rendered inoperable (e.g., cutting into pieces or filling the reactor core with concrete) before its shipment for disposal. The reactor site could be periodically observed using thermal imaging from a satellite to confirm that the reactor has not resumed operation. The frequency of verification activities should be based on the estimated length of time required for restart of the facility given its state of decommissioning.
- **Bulk processing facility** - centrifuge enrichment plant: Until removal and destruction of the centrifuges, the primary safeguards activity will remain verification that the cascades have not been restarted. Remotely accessed power or electromagnetic frequency monitors could be used to verify that power is not

being provided to the centrifuges in the cascades.¹⁴ The facility could be requested to voluntarily report where equipment listed in Annex II of the AP (e.g., centrifuge assemblies and feed and withdrawal stations) is being moved (with the IAEA using AP Article 8, Article 5(b) for equipment or materials confirmed by the State as imported under Article 2.a.(ix), or Article 5(c) for access to confirm the information).¹⁵ In accordance with the DIE/DIV procedure, DIVs should be performed as necessary to verify that essential equipment was rendered inoperable (e.g., crushing of centrifuges) before its shipment for disposal. The frequency of verification activities should be based on the estimated length of time required for restart of the facility given its state of decommissioning.

11. Conclusions.

The above discussion illustrates the level of effort the IAEA currently expends to safeguard non-operating facilities, in particular those being decommissioned, and that there is potential for optimizing this effort, using the concepts discussed that could be applied on a facility-by-facility basis. Member State Support Program projects for the IAEA on decommissioning have demonstrated large variability between decommissioning processes for facility types such that each facility needs to be considered separately. Periodic DIE and DIV during decommissioning provide information for an IAEA management decision as to when a facility can be considered ‘decommissioned for safeguards purposes’. Because of differences in decommissioning processes, this decision must be made by expert judgment for each facility as to when sufficient essential equipment has been removed or rendered inoperable.

This study finds that the measures specified in the IAEA’s DIE and DIV guidance should permit the IAEA to implement efficient safeguards at facilities undergoing decommissioning and that no fundamental changes are needed in the safeguards approaches for shutdown or closed-down facilities. From an efficiency perspective, no change would be expected in the safeguards approach for safeguarding an operating facility versus a shutdown facility, but it has been illustrated that for closed-down facilities, in particular those being decommissioned, certain changes to safeguards implementation could be made to enhance the effectiveness and efficiency of the safeguards activities.

¹⁴ Power and electromagnetic frequency monitoring was proposed and tested for use under a Fissile Material Cutoff Treaty, but have not been implemented by the IAEA.

¹⁵ We are not aware of the IAEA having used these additional protocol articles to gain access to removed equipment.

The following activities could be pursued to improve the effectiveness or efficiency of safeguards for shutdown and closed-down facilities, including those undergoing decommissioning:

1. Tracking of removed essential equipment. For a facility being decommissioned, one key weakness is that there are inadequate safeguards measures to ensure that equipment removed from the facility is not misused elsewhere. Verification is only possible if equipment remains on site or on the site of another declared facility. There is no legal instrument that provides for the monitoring of AP Annex II equipment within a country – only its import (and manufacture if also listed in Annex I). This gap has been identified in an earlier NA-241 sponsored report on amending the annexes of the Model Additional Protocol with the suggestion to add the storage of Annex II equipment (either new or used) as a reportable Annex I activity.¹⁶ Such a change to the AP Annexes would be required because, if the equipment was imported before the AP or was domestically produced, reporting on the location under AP Article 2.a.(ix)(b) would not apply. Where Annex I addresses manufacturing and Annex II addresses import and export, and DIVs address installed equipment at a facility, the location and status of equipment removed during maintenance, upgrading, or decommissioning is not covered. This additional reporting would only be needed for removed equipment that has not been verified to have been rendered inoperable.
2. Design information updates. NNSA should engage with the IAEA to determine if the IAEA is getting sufficient and timely information on design information changes. If the IAEA is not getting the necessary information from certain States, the IAEA should re-emphasize to these States the obligation and importance of providing timely updates of design information, including facility status and schedules, throughout the non-operating lifecycle phases. IAEA-State discussions should be held to ensure early identification of schedules of activities relevant to the shutdown, closed-down, and decommissioning periods.
3. Guidance documents. NNSA should also engage with the IAEA to determine the usefulness of a new design information questionnaire template for non-operating facilities and a safeguards by design document on the decommissioning process. Although the decommissioning process for each type of facility is different, a new DIQ template could better focus the information provided by the State on that needed by the IAEA during the process. A

¹⁶ Warren Stern et al, “Considerations for Amending the Annexes to the Additional Protocol”, BNL-112497-2016, Brookhaven National Laboratory, August 2016.

safeguards by design document for facilities undergoing decommissioning could provide guidance on the safeguards issues associated with the decommissioning process.