OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

ORNL/TM-2013/278

Preliminary Concept of Operations for a Global Cylinder Identification and Monitoring System

August 2013

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UT-BATTELLE

ORNL-27 (4-00)

ORNL/TM-2013/278

Nuclear Security and Isotope Technology Division

PRELIMINARY CONCEPT OF OPERATIONS FOR A GLOBAL CYLINDER IDENTIFICATION AND MONITORING SYSTEM

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Date Published: August 2013

Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6283
managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

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ACKNOWLEDGEMENT

This work was sponsored by the U.S. Department of Energy/National Nuclear Security Administration through the Next Generation Safeguards Initiative. The paper reflects the work of a multi-laboratory team and their subcontractors. The authors are pleased to acknowledge the contributions to this project by Sean Branney (Savannah River National Laboratory), Ed Wonder (QinetiQ North America), Brian Boyer and Carolynn Scherer (Los Alamos National Laboratory), Michael Curtis and Travis Gitau (Pacific Northwest National Laboratory), and Dan Collier (NAC International).

Engaging stakeholders of the UF_6 cylinder industry has been a fundamental ingredient throughout the execution of this project. The authors are especially appreciative of representatives of the following companies who hosted visits and provided comments and suggestions on the preliminary concept of operations: Urenco, Westinghouse, Global Nuclear Fuels, United States Enrichment Corporation, Cameco, Converdyn/Honeywell, and Worthington.

ABBREVIATIONS

EURATOM	European Atomic Energy Community
HEU	highly enriched uranium
HF	hydrogen fluoride
IAEA	International Atomic Energy Agency
LEU	low-enriched uranium
MBA	material balance area
MC&A	material control and accounting
NNSA	National Nuclear Security Administration
NNWS	non-nuclear weapons state
NWS	nuclear weapons state
PIV	physical inventory verification
SQ	significant quantity
SSAC	State System of Accounting and Control of Nuclear Material
SWU	separative work unit
UID	unique identifier
UF_6	uranium hexafluoride

EXECUTIVE SUMMARY

This report describes a preliminary concept of operations for a Global Cylinder Identification and Monitoring System that could improve the efficiency of the International Atomic Energy Agency (IAEA) in conducting its current inspection activities and could provide a capability to substantially increase its ability to detect credible diversion scenarios and undeclared production pathways involving UF_6 cylinders. There exist concerns that a proliferant State with access to enrichment technology could obtain a cylinder containing natural or low-enriched uranium hexafluoride (UF_6) and produce a significant quantity (SQ)[1] of highly enriched uranium in as little as 30 days.

The National Nuclear Security Administration (NNSA) through the Next Generation Safeguards Initiative sponsored a multi-laboratory team to develop an integrated system that provides for detecting scenarios involving 1) diverting an entire declared cylinder for enrichment at a clandestine facility, 2) misusing a declared cylinder at a safeguarded facility, and 3) using an undeclared cylinder at a safeguarded facility. An important objective in developing this integrated system was to improve the timeliness for detecting the cylinder diversion and undeclared production scenarios. Developing this preliminary concept required in-depth analyses of current operational and safeguards practices at conversion, enrichment, and fuel fabrication facilities. The analyses evaluated the processing, movement, and storage of cylinders at the facilities; the movement of cylinders between facilities (including cylinder fabrication); and the misuse of safeguarded facilities.

This preliminary concept of operations utilizes an approach for providing a standardized unique identifier (UID) for all model 30B and 48Y UF_6 cylinders and creating a Global Cylinder Identification and Monitoring System. The monitoring system design includes four primary components: (1) a standardized, remotely readable, tamper-indicating UID to be applied to each cylinder, (2) UID readers (portable and installed) at cylinder-handling facilities, (3) an access-controlled, global cylinder registry (or database), and (4) an IAEA safeguards cylinder monitoring system (for use at safeguarded facilities).

The UID is the cornerstone of the monitoring system. Key requirements for the UID include that they be

- tamper indicating,
- equipped with a characteristic that provides for the "authentication," and
- capable of being automatically read or scanned by a UID reader, both portable and unattended.

A fundamental feature of the UID is that it could be independently used by both the plant operator and the IAEA. Portable reader systems could be used by operators and inspectorates to independently read the cylinder UIDs. Separate databases could be utilized by the operators and inspectors to capture and manage their cylinder information to meet their specific reporting and monitoring requirements. Having a tamper-indicating UID that is acceptable to the IAEA for safeguards purposes could improve the efficiency of the IAEA verification activities.

The monitoring system would collect cylinder-related information concerning the last reported location of all cylinders (empties and those containing UF_6). An access-controlled global cylinder registry would collect information on UF_6 cylinders in both nuclear weapons States and non-nuclear weapons States. This registry would receive inputs from facility operators and cylinder handlers and could be periodically downloaded by the IAEA. The cylinder location information in the global cylinder registry could significantly improve the IAEA's timeliness in detecting the diversion of cylinders during transport and provide information that could optimize the scheduling of inspections and on-site inspection activities. It is important to emphasize that the concept is for the registry system to maintain information only on the

[1] The IAEA defines HEU as uranium enriched to ≥20% ^{235}U and a SQ of HEU as being 25 kg ^{235}U.

last reported strategic location for each registered cylinder – it is not a real-time system that "actively" tracks the cylinders as they move from location to location.

Utilizing flow diagrams of undeclared production pathways identified in the initial task of this project, the team developed a concept that provides for placing unattended UID readers at strategic operating locations (e.g., feed stations, withdrawal stations, transfer and sampling stations, etc.). Operators could use these systems to meet their regulatory requirements for detecting unauthorized production and the IAEA could use the systems for continual assurance that only declared cylinders are being processed. The IAEA UID readers could provide input to on-site IAEA databases, which would store cylinder information and would contain algorithms that could assist in determining the presence of undeclared or "unregistered" cylinders and/or the misuse of the safeguarded facilities. An off-site, centralized IAEA database would receive inputs from the on-site IAEA databases installed at the IAEA safeguarded facilities. The listing of all the cylinders in circulation and the location of those cylinders in particular countries and facilities could assist the IAEA in identifying undeclared or unregistered cylinders. The use of the centralized IAEA database could assist the IAEA in monitoring cylinder theft, loss, or misuse. Safeguards algorithms could be developed to provide "flags" or "notifications" when updated cylinder information is needed to address the timely response for ensuring that material theft and/or facility misuse is not occurring. These notifications do not automatically "trigger" an inspection but would provide information that could be used in planning activities during scheduled and unannounced inspections. The IAEA has reported that the strategic use of unattended instrumentation could reduce or eliminate the need for routine interim inspections.

The IAEA could gain increasing benefits from the implementation of each component of the proposed global cylinder identification and monitoring system. A standardized cylinder identification format used across the industry would improve reporting to the State Systems of Accounting and Control and the IAEA by reducing reading and transcription errors and could enable the IAEA to improve its efficiency in reconciling international transfers (i.e., transit matching). Having a tamper-indicating UID that is designed to be machine-readable could improve the IAEA's efficiency in performing current on-site inspection activities by reducing the time required to inventory cylinders. If the IAEA were able to install unattended readers at strategic operating locations, its ability to detect undeclared production involving the misuse of declared cylinders or the introduction of undeclared cylinders could be significantly increased by having a means to verify that only declared cylinders are being processed.

Incremental gains in both efficiency and effectiveness could be realized even if the concept is implemented in phases:

- A standardized cylinder identification format used across the industry would improve reporting to the SSACs and the IAEA by reducing reading and transcription errors.

- A tamper-indicating, machine-readable cylinder identification could improve efficiencies in conducting cylinder inventories.

- A registry of the cylinder identification number and last reported location of all cylinders could improve timeliness in detecting the diversion of declared cylinders from sites or during transportation and provide information to optimize scheduling of inspection and inspection activities.

- The use of unattended cylinder monitoring instrumentation at strategic operating locations could significantly improve capabilities for detection undeclared operations and could potentially reduce or eliminate routine interim inspections.

In defining the functional and performance requirements and developing the preliminary concept of operations, the project team has been careful to not “jump to a solution” by pre-selecting a particular UID technology (e.g., barcode, radio-frequency identification device, etc.). The next project phase includes investigating available technologies and down selecting options. This process will further define the necessary interfaces among the UIDs, the UID readers, the Global Cylinder Registry, and the IAEA cylinder monitoring system to achieve the performance requirements for detecting the diversion and undeclared production scenarios and will consider, among other factors, the total life-cycle costs. Additional work is needed on architecture design and global registry operation. The phased-implementation strategy needs to be further developed and discussed among stakeholders. Ultimately it would be desirable for the UID to be applied during the initial fabrication of the cylinder, but during a phased-in transition period, it is anticipated that the UIDs could be applied as part of the cylinder certification process (required every 5 years). Key components and operational aspects will need to be tested and evaluated in operational settings. Throughout these next steps, engagement with key stakeholders will continue to be a priority to ensure that both concerns and desires are identified and integrated into the design. This concept provides a basis for detailed discussions with industry, national authorities, and inspectorates and will continue to evolve in response to the content of these discussions.

1. INTRODUCTION

With growing nuclear commerce and new safeguards initiatives to achieve International Atomic Energy Agency (IAEA) verification objectives, the international safeguards system continues to face ever-increasing demands to verify nuclear materials and detect clandestine activities. Emerging proliferation threats from both State and non-State actors are also leading to increased concerns over the diversion of nuclear materials; for example, the diversion of cylinders containing uranium hexafluoride (UF_6) or the introduction of undeclared feed into enrichment plants.

There exist concerns that a proliferant State with access to enrichment technology could obtain a cylinder containing natural or low-enriched UF_6 and produce a significant quantity (SQ)[2] of highly enriched uranium (HEU) before detection. While the IAEA timeliness goal for detecting the diversion of a SQ of natural or low-enriched uranium (LEU) is 1 year, a proliferant State, given a worst-case scenario, could convert this material to HEU in as little as 30–90 days using a moderately sized enrichment facility with a separative capacity of 10,000–25,000-kg separative work units (SWU)/year. The enrichment could theoretically be performed at either a clandestine facility or by misusing a portion of a safeguarded facility. Thus, the production time necessary to produce a SQ of HEU from a diverted cylinder can be much less than the current timeliness goals for detecting the diversion.

This report presents a multi-phased global cylinder identification and monitoring project sponsored by the National Nuclear Security Administration (NNSA). The report reviews key findings and recommendations from the initial task, introduces overall performance requirements for the global monitoring system, describes a preliminary concept of how a global monitoring system might operate and how the international safeguards regime could be strengthened, and assesses the potential impacts on the key stakeholders. A glossary of key terms associated with this project is provided in Appendix A.

[2] The IAEA defines HEU as uranium enriched to ≥20% ^{235}U and a SQ of HEU as being 25 kg ^{235}U.

2. NNSA GLOBAL CYLINDER IDENTIFICATION AND MONITORING PROJECT

The NNSA initiated a 5 year program in 2011 to demonstrate, at the proof-of-concept level, a UF_6 cylinder identification and monitoring system.[3] This program builds upon prior exploratory studies sponsored by NNSA and also upon work by several industry leaders on the merits of unique identifiers for UF_6 cylinders.[4,5] The primary objective of the NNSA program is to develop and demonstrate a concept for a global cylinder identification and monitoring system that could substantially increase the effectiveness and efficiency of the IAEA to detect credible diversion of a UF_6 cylinder and undeclared production pathways before a SQ of HEU could be produced.

The program has six principal tasks: 1) define the problem, 2) establish requirements for a unique identifier (UID) and cylinder monitoring system and develop a concept of operations, 3) determine cylinder monitoring devices and technology, 4) develop a registry database to support proof-of-concept demonstration, 5) integrate a prototype system for demonstration, and 6) demonstrate a proof of concept. Engaging significant stakeholders throughout the program is fundamental to building support for the program's direction and path forward and in successfully demonstrating the proof of concept. Discussions have already taken place with industry leaders, cylinder users, and international safeguards experts including the IAEA, the European Atomic Energy Community (EURATOM), and representatives from several State Systems of Accounting and Control of Nuclear Materials (SSACs). Furthermore, the program team has evaluated and incorporated recommendations from previous national laboratory studies sponsored by NNSA and workshops on UF_6 cylinder issues.[6]

2.1 REVIEW OF TASK 1: PROBLEM DEFINITION AND BASELINE

Task 1 defined the nonproliferation concerns related to cylinder diversion and facility misuse. It also provided a basis for the global cylinder identification and monitoring concept through documenting the life cycle of a cylinder, identifying diversion and undeclared HEU production pathways, assessing the current capabilities of the international safeguards regime for detecting these diversion and undeclared production scenarios, engaging key stakeholders, and reviewing national and international cylinder standards.[7] The HEU production pathways fall into three areas:

- diverting an entire declared cylinder from a safeguarded facility to a clandestine facility,
- misusing a declared cylinder at a safeguarded facility, and
- introducing undeclared material into a safeguarded facility (via an undeclared cylinder).

The project team produced four technical reports defining the nonproliferation concerns and documenting current industry and safeguards practices:

1) The life cycle of model 30B and 48Y cylinders[8]
2) Cylinder diversion and undeclared production pathways[9]

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[3] K. Durbin, M. Whitaker, E. Wonder, "Overview of Next Generation Safeguards Initiative UF_6 Cylinder Monitoring Program," 35th ESARDA Conference, Bruges, Belgium, May 2013.
[4] G. Eccleston et al., *Monitoring Uranium Hexafluoride (UF_6) Cylinders*, ORNL/TM-2009/128, June 2009.
[5] P. Friend, D. Lockwood, D. Hurt, "A Concept for a World-wide System of Identification of UF_6 Cylinders," ESARDA Symposium, Lithuania, May 2009.
[6] F. Keel, "Results of the Cylinder Identification, from Point to Manufacture to Final Disposition," for the Transport of Uranium Hexafluoride (UF_6) Workshop, INMM Annual Meeting, 2011.
[7] M. Whitaker et al., *Global Cylinder Identification and Monitoring System: Nonproliferation Concerns and Baseline Definition*, ORNL/TM-2013/169, May 2013.
[8] J. L. White-Horton et al., *The Life Cycle of 30B and 48Y Cylinders*, ORNL/TM-2011/522, April 2011.
[9] S. Branney et al., *Identifying UF_6 Cylinder Diversion and Undeclared Production Pathways*, SRNL, January 2012.

3) Detection of diversion and undeclared production[10]
4) Developing an international standard for uniquely identifying UF_6 cylinders[11]

Key findings from the initial task included:

- The number of cylinders transported globally between facilities is relatively small, estimated at <20,000 per year (~9,000 model 48Y cylinders of natural uranium and ~7,000 model 30B cylinders of LEU). Additionally ~8,000 model 48Y cylinders are filled with depleted tails material and placed in long-term, on-site storage each year.[12]

- Cylinders are exposed to a variety of operating conditions; the most extreme conditions involve withstanding a wide temperature range and exposure to hydrogen fluoride (HF) gas.

- Due to use as pressure vessels, cylinders must not be filled unless they have been certified within the previous 5 years.

- National and international standards for cylinder fabrication specify minimum requirements for marking and labeling, but do not specify a truly unique numbering format that could be applied industry wide.

- The identification information on the UF_6 cylinder nameplate is often difficult to read.

- Because the nameplates can be difficult to read, many companies apply a variety of supplemental markings and identification numbers to the cylinders for their on-site material control and accounting (MC&A) purposes. The presence of multiple markings and labels on individual cylinders can create confusion in determining the actual identification number used on various site and State reports and in reconciling cylinder identification information received from multiple sources.

- The IAEA is not currently using any of the supplemental cylinder markings and identification labels because the schemes are not tamper-resistant.

The team also compiled the following key recommendations for use in developing functional requirements for a global UID and monitoring system:

- The UID should have a minimum life expectancy of 10 years (currently many cylinders remain in circulation 30–40 years).

- The UID must be designed to function in all the operating conditions including the wide temperature range and exposure to HF gas.

- The UID should be designed in a manner such that it can be located on the same end of the cylinder as the cylinder valve.

- The UID should have the capability to be automatically scanned or read in some fashion to eliminate the potential for transposition errors.

[10] M. Curtis et al., *Methods of Detecting Diversion and Undeclared Use of UF_6 Cylinders*, PNNL-22017, November 2012.
[11] Carolynn Scherer and Brian Boyer, *Developing an International Standard for Identifying Uranium Hexafluoride Cylinders*, LA-UR-12-01286, LANL, February 2012.
[12] G. Eccleston et al., *Monitoring Uranium Hexafluoride (UF_6) Cylinders*, ORNL/TM-2009/128, June 2009, p. vii.

- The UID could be applied to existing cylinders either during the recertification process or when they are returned to conversion or enrichment plants to be refilled.

- Until the current cylinder fabrication standards are revised, conversion plants would likely be the best place to apply UIDs for new, empty model 48Y cylinders, and enrichment plants would likely be the best place for UIDs to be applied to new, empty model 30B cylinders. For cylinders currently in circulation, the cylinder recertifying location would be the best place to apply the new UIDs.

2.2 DIVERSION AND UNDECLARED PRODUCTION PATHWAYS

During the initial task, a variety of cylinder diversion and undeclared production scenarios were described and evaluated. These scenarios were categorized into the three HEU production pathways as provided in Table 1.

Table 1. Diversion and undeclared production pathways

Diverting an entire declared cylinder for enrichment at a clandestine facility	Misusing a declared cylinder at a safeguarded facility	Using an undeclared cylinder at a safeguarded facility
Diverting a declared cylinder from a safeguarded facility (conversion, enrichment or fuel fabrication) - 48Y with natural UF_6 - 30B with low-enriched UF_6	Feeding a declared cylinder containing an unexpected enrichment at an enrichment facility (e.g., feeding LEU from a 30B cylinder)	The presence of an undeclared cylinder in a feed/withdrawal station
Diverting a declared cylinder during shipment between facilities - between conversion and enrichment - between enrichment and fuel fabrication	Misusing a declared cylinder - Transferring the UF_6 from a declared cylinder to an undeclared cylinder - Using a declared "empty" cylinder filled with undeclared material	The presence of an undeclared cylinder on-site
	Reusing of a cylinder slated for decommission/destruction with undeclared material	Applying duplicate nameplates to an undeclared cylinder

In assessing the current international safeguards methods for detecting these cylinder diversion and undeclared production pathways, the conclusions were that current IAEA safeguards measures: (1) cannot effectively detect all the credible scenarios for diverting an entire UF_6 cylinder before an SQ of HEU could be clandestinely produced, (2) have limited capabilities for detecting undeclared production scenarios using undeclared feed, (3) have limited capabilities for recognizing undeclared cylinders in a country, and (4) do not provide for generating an inventory listing of all of a country's cylinders (including empty cylinders).[13] Additionally, the time frames for the IAEA to reconcile the transfer of cylinders between States (i.e., transit matching) can take 6–12 months, which is significantly longer than the 30–90 day HEU SQ production time frame.

As a result of this analysis, the team made recommendations related to the design of a global cylinder identification and monitoring system:

[13] M. Whitaker et al., *Global Cylinder Identification and Monitoring System: Nonproliferation Concerns and Baseline Definition*, ORNL/TM-2013/169, May 2013.

- The time required to confirm a cylinder transfer between facilities should be shortened to the minimum time required to convert its contents to HEU using a small to moderately sized enrichment facility (i.e., 30 days for a LEU cylinder and 90 days for a natural cylinder).

- Cylinders containing more than an SQ that are placed in static storage should be randomly inventoried more frequently than once a year.

- Additional safeguards measures for continuously monitoring throughput at conversion and enrichment facilities are needed to address the undeclared production scenarios. A cylinder identification and monitoring system could be a key enabler of a robust safeguards approach that incorporates such additional measures.

- Should a cylinder be diverted from a site or during transport, some form of cylinder monitoring or surveillance would prove helpful by establishing the last known location of the cylinder.

- A complete "registry" of all UF_6 cylinders, coupled with a capability to read the UID on "registered" cylinders at strategic processing locations in a safeguarded facility, could significantly increase the capability of quickly recognizing the presence of any unregistered cylinders. A registry of cylinders would also improve the IAEA capability to match transfers between countries.

- Cylinder monitoring would also prove valuable in detecting scenarios involving content swapping or nameplate switching.

- Monitoring the location of empty cylinders would prove valuable in detecting scenarios involving feeding undeclared material.

3. GLOBAL CYLINDER IDENTIFICATION AND MONITORING SYSTEM

The second project task involved establishing requirements for a global cylinder identification and monitoring system and developing a concept for how the system would operate. A primary objective of the concept was for the system to provide a capability for detecting all credible cylinder diversion and undeclared production pathways. The team performed a risk assessment in which each pathway was evaluated in terms of:

- Consequences of material diversion and/or facility misuse
- Minimum time to produce 1 SQ of HEU
- Attractiveness of the material in the cylinder
- Relative difficulty for detection by current IAEA practices
- Relative attractiveness of the scenario by a proliferator

A summary of the results of the risk assessment are provided in Appendix B. These results were then used to create *overall performance requirements* for the system.

3.1 OVERALL PERFORMANCE REQUIREMENTS

Performance requirements were established to address the diversion and undeclared production pathways defined in the initial task (Table 1 in Section 2.2). Using the time estimated to produce a SQ of HEU at a clandestine enrichment plant or by misusing a portion of a safeguarded enrichment plant, a timeliness component was introduced into each requirement. Assuming a worst-case scenario (a proliferant State with access to adequate enrichment capabilities), the following timeliness components were assigned: 30 days for a cylinder containing LEU, 90 days for a cylinder containing natural materials, and 180 days for a cylinder containing depleted material.

For each performance requirement, the system would generate a “notification” when conditions associated with the pathway occur (e.g., the presence of an unregistered cylinder, an unregistered cylinder is placed in a feed station, a declared cylinder has shown no activity over an extended period of time, etc.). These notices can then be used by the IAEA when planning inspection activities. ***It is essential to emphasize that the notices described in the requirements below do not automatically “trigger” an inspection, but could provide information to be used in planning verification activities during scheduled and unannounced inspections.***

Given that the timeframes used in these performance requirements assume the worst-case scenario, the actual notification timeframes to be applied at individual facilities can be adjusted based on specific factors associated with the State (e.g., the IAEA has reached a broader conclusion that there are no undeclared activities). The performance requirements are grouped according to the HEU production pathway.

1. For indicating the potential diversion of an entire declared cylinder (either from a safeguarded facility or during shipment between facilities) to a clandestine facility:
    a. *The system **shall** provide a notification if there is no on-site activity associated with a declared cylinder*
        i. *within 30 days for a cylinder containing LEU.*
        ii. *within 90 days for a cylinder containing natural uranium.*
        iii. *within 180 days for a cylinder containing depleted uranium.*
    b. *The system **shall** provide notification if a shipped cylinder has not arrived at its destination within **90** days of its ship date.*

2. For indicating the potential misuse of a declared cylinder at safeguarded facilities:
    a. *The system **shall** provide notification if a declared cylinder is placed in a processing operation (e.g., feed station) but has not been reported as being received at the facility.*
    b. *The system **shall** provide notification if a cylinder destined for destruction or decommission is placed in a feed or withdrawal station at conversion, enrichment, or fuel fabrication plants.*
    c. *The system **shall** provide notification if a declared cylinder (declared to be empty) is processed (e.g., is placed in a feed station).*
    d. *The system **shall** provide notification of the presence of declared cylinders with an unexpected enrichment*[14] *in a feed station at an enrichment plant.*
        i. *The presence of a cylinder whose last reported activity was at a LEU withdrawal station.*
        ii. *The presence of a registered cylinder whose last reported activity was decommissioning or destruction (and since has been filled with undeclared material).*

3. For indicating the presence and use of unregistered cylinders containing undeclared materials at safeguarded facilities:
    a. *The system **shall** provide notification of the presence of any unregistered cylinder in a feed or withdrawal station at a safeguarded facility.*
    b. *The system **shall** provide notification of the presence of an unregistered cylinder on-site upon discovery.*
    c. *The system **shall** provide notification if a given cylinder ID is processed at different facilities within the same time period or if processed multiple times within a facility (e.g., duplicate cylinder UIDs).*

While a system designed to meet these requirements will generate "notifications" within the provided timeframes, the actual notification to the IAEA can be somewhat longer depending on the actual installation constraints. For example, one of the requirements is for the system to provide a notification of the presence of any unregistered cylinder in a feed or withdrawal station. If the system is allowed to have a real-time remote monitoring capability, the notification can be immediate. But, if the site allows only one remote message/day, the notification could be delayed up to 24 hours. If off-site transmissions are not allowed, then the notification would be delayed until the next time an inspector visits the site and accesses the system notifications.

3.2 OPTIONS FOR THE CONCEPT OF OPERATION

In developing the concept of operations for a global cylinder identification and monitoring system, the design team considered six options that were either introduced in a 2009 report on monitoring UF_6 cylinders[15] or added to address the diversion and undeclared production pathways. These options, described below, range from only monitoring the transfer of cylinders between States to a capability to request an "inventory upon demand."

- **Transfers between States:** Identifies and monitors the movement and transfer of the cylinder from one State regulatory agency to another.

[14] The monitoring system is not being designed to record the specific enrichment of the material in a cylinder, but an enrichment stratum (depleted, natural, or enriched) can be assumed based on last reported operation (e.g., filling at conversion plant, placement in product withdrawal, etc.).
[15] G. Eccleston et al., *Monitoring Uranium Hexafluoride (UF_6) Cylinders*, ORNL/TM-2009/128, June 2009.

- **Transfers within State:** Identifies and monitors the movement and transfer of the cylinder under the oversight of the same State regulatory agency.

- **Site Arrival/Departure:** Identifies and monitors the arrival and departure of cylinders at individual nuclear facilities.

  - Cylinder information is identified and transmitted during receipt of cylinders to each facility.
  - Cylinder information is identified and transmitted during shipment of cylinders from each facility.

- **Crossing Material Balance Area (MBA) Boundaries:** Identifies and monitors the movement of cylinders across MBA boundaries within individual nuclear facilities.

  - Cylinder information is identified and transmitted as cylinders across MBA boundaries

  - Information regarding contents of cylinder is provided externally to the IAEA cylinder monitoring system.

- **Cylinder Presence at Key Operational Nodes/Measurement Points:** Identifies and monitors the movement of cylinders as they are utilized at strategic operating points within the facility (e.g., feed stations, withdrawal stations, sampling stations, accountability scales, storage lots, staging areas, blending stations, etc.).

- **Cylinder Inventory upon Demand:** Provides the capability to determine the location of all cylinders within a facility within a specified amount of time.

The team evaluated the capability of each of the six options to meet the overall performance requirements. Individually, none of the options provided a means to detect all of the pathways, so a hybrid option (as described below) was created, taking features from multiple options to ensure complete coverage. Appendix C provides more information on the six options and their assessed capabilities for detecting the specific diversion and undeclared production pathways.

3.3 PRELIMINARY CONCEPT OF OPERATIONS

Developing a preliminary concept of operations required in-depth analyses of the cylinder diversion and undeclared production pathways. These analyses considered the IAEA safeguards objectives; cylinder storage, processing, and movement practices within facilities (conversion, enrichment, and fuel fabrication); the movements of cylinders between facilities; and scenarios for misusing safeguarded facilities.

It is important to distinguish "monitoring" from "tracking." For the purposes of this report, the authors define the terms as:

Monitoring: *A practice that provides the location and status of all UF_6 cylinders in the commercial nuclear fuel cycle.*

Tracking: *Actively following the path or trail of a cylinder as it moves from location to location.*

The concept of operation being developed is for a "monitoring" system that maintains information on the location and status of each registered cylinder. The preliminary conceptual design includes four primary components:

- a standardized, remotely readable, tamper-indicating UID to be applied to each cylinder,
- UID readers (portable and installed) at cylinder-handling facilities,
- an access-controlled, global cylinder registry (or database), and
- an IAEA safeguards cylinder monitoring system (for use at safeguarded facilities)

The integration of these components is illustrated in Fig. 1.

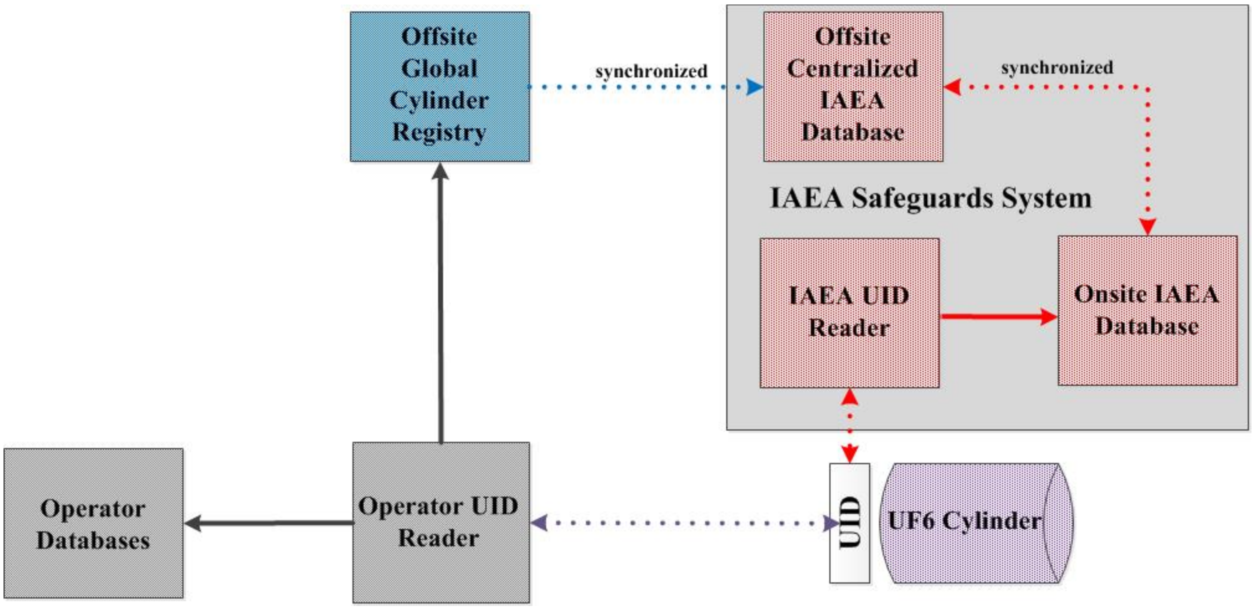

Fig. 1. Fundamental components of conceptual global cylinder identification and monitoring system.

3.3.1 Unique Identifier (UID)

The UID is the cornerstone of the global cylinder identification and monitoring system. Each cylinder would have a UID that can be used for identification and monitoring and would be designed for use across the entire UF_6 cylinder industry. Initially, the focus would be on model 30B and 48Y cylinders in active circulation. A fundamental feature of the UID is that it can be independently used by both the plant operator and the IAEA. The initial functional requirements developed for the UID are provided in Appendix D. High-level functional requirements include the following:

- Standardized format/design

- Truly unique across all industry

- Tamper-indicating for use by IAEA for safeguards purposes

- Contains necessary characteristics to provide for authentication
- Capability to be remotely read (e.g., machine readable)
- Would not replace the current cylinder nameplate but can be correlated with the identification number stamped on the nameplate
- Useable by both the operator and the IAEA
- Ability to withstand environmental conditions and cylinder handling practices
- Capability to be applied at either the cylinder fabricator or in the field
- Minimum life expectancy of 10–30 years

The initial feedback from industry (Section 5) has indicated general agreement with these high-level requirements. The use of a standardized UID could provide many direct benefits to the international safeguards regime and to industry. A standardized cylinder ID could produce immediate improvements in reporting to State authorities and to the IAEA by reducing reading and transcription errors.[16,17,18] The industry's use of a standardized format could eliminate the need for each company to apply supplemental labels and identification numbers to the cylinders that add confusion to various reporting systems. Eliminating multiple identifiers will directly benefit the IAEA in reconciling cylinder transfers between facilities and countries and in verifying facility records during on-site inspections. This could save significant time during inspections, benefiting both the IAEA and the operator.

The UID would be tamper indicating and equipped with a characteristic that provides for "authentication." Having a tamper-indicating UID that is acceptable to the IAEA for safeguards purposes could improve the efficiency of the IAEA in verifying cylinder IDs in the cylinder yards. Accessing and trying to read the tiny ID number stamped on the nameplates at the end of the cylinders can be time-consuming. Applying the UID at a more observable location would streamline this routine, repetitive inspection activity. Having an authentic, tamper-indicating UID would also give the inspector increased confidence that the cylinder identifier had not been falsified in an effort to conceal a diversion or facility misuse, thereby enhancing the effectiveness of IAEA safeguards. Initial discussions with the IAEA have led to a list of desirable features for the UID, but a detailed list of IAEA user requirements have not yet been produced.

Designing the UID to be read remotely would substantially reduce the time required for the IAEA to verify cylinder inventories during on-site inspections (provided that the IAEA can use their own portable UID readers during inspections). This quicker cylinder inventorying capability would provide increased overall efficiency with two important benefits: 1) during normal inspections, inspectors would be able to locate and verify declared cylinders much quicker, leaving more time for activities to detect undeclared production pathways (e.g., design verification, looking for undeclared cylinders and operations), and 2) the IAEA could verify "static" cylinder inventories more frequently than once a year during physical inventory verifications (PIVs) if such increased frequency was deemed necessary. Portions of the static inventories could be verified on a random basis during scheduled or unannounced inspections to address

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[16] R. Martyn, P. Fitzgerald, N. Stehle, N. Rowe, J. Younkin, "An Operator Perspective from a Facility Evaluation of an RFID-Based UF_6 Cylinder Accounting and Tracking System," INMM Annual Meeting, Palm Desert, CA, July 2011.

[17] P. Friend, A. Johnson, B. Engbers, "URENCO's Position on Standardising the Identification of UF_6 Cylinders," INMM Annual Meeting, Palm Desert, CA, July 2011.

[18] C. Pickett et al., *Results from a Demonstration of a RF-Based UF_6 Cylinder Accounting and Tracking System Installed at a USEC Facility*, ORNL/TM-2008/189, September 2008.

the diversion and undeclared production pathways. Additionally, this ability to automate inventories would reduce the radiation exposure of inspectors, especially in the areas containing emptied cylinders.

3.3.2 UID Readers

The UID readers could either be handheld systems or installed, unattended systems. Operators, regulators, and the IAEA inspectors could have independent and/or shared capabilities for reading the cylinder UIDs. Unattended readers could be installed at strategic locations that could benefit operators and/or IAEA (e.g., cylinder receipt and dispatch areas, accountability scales, feed stations, etc.). For unattended readers, the information for reading cylinder UIDs would likely need to be integrated with a cylinder database to verify that a read UID is in fact present in the database. Cylinders read for the first time (and not in the database) would need to be "registered" (i.e., to issue/record the ID).

The operator would have the capability to read the cylinder UID and enter information into facility databases that monitor information related to the location, status, and utilization of cylinders. Any negotiated IAEA system could collect information through the use of unattended readers, as well as hand-held readers that may be utilized by inspectors during on-site inspections. Information to be submitted to a global registry could be collected either manually, with hand-held readers, or with unattended reader systems.

3.3.3 Access-Controlled, Global Cylinder Registry

An access-controlled global cylinder registry (Registry) would be established to maintain location and status information on all UF_6 cylinders in both Nuclear Weapons States (NWSs) and Non-nuclear Weapons States (NNWSs). The Registry would receive from the facility operators and/or national authorities such cylinder-related information as:

- UID
- Facility location
- Date
- Cylinder owner
- Status of cylinder (full, empty, material type)

The registry could compile the received information with cylinder-related information from other existing sources, such as the following:

- Fabrication of new cylinders
- Destruction of old or damaged cylinders
- Shipments of empty cylinders
- Cylinders containing UF_6 at IAEA safeguarded facilities
- Shipments of UF_6 between IAEA safeguarded facilities
- Cylinder inventories in NWSs

For IAEA-safeguarded facilities, the safeguards-related information in the registry could be periodically synchronized or downloaded to a IAEA cylinder-monitoring system. Combining information from this global registry with current IAEA safeguards activities could provide for more timely detection of diversion and undeclared production of enriched UF_6. The IAEA would have a capability to generate a list of all cylinders in the State, which could support State evaluations, annual inspection planning, and acquisition path analyses. A registry could also be especially valuable in IAEA efforts to reconcile cylinder transfers (i.e., transit matching) in a more timely manner if information on cylinder shipments and receipts were submitted to the registry in a much more timely manner (e.g., 1–2 weeks). The IAEA could then be able access information to reconcile shipment and receipt information much more quickly than current submissions (up to 60 days).

Of fundamental importance, the registry could provide the IAEA with a technical basis for recognizing unregistered (potentially undeclared) cylinders. Depending on how frequently information is submitted to the registry and how frequently the IAEA safeguards department accesses the registry, it is possible that IAEA inspectors could have access to cylinder receipt information prior to inspecting facilities. This information would be valuable in planning inspections (especially for unannounced or short-notice random inspections) and verifying operator receipts records.

Finally, for States in which the IAEA has reached the broader conclusion, implementing a cylinder monitoring system would demonstrate transparency in regards to cylinder inventories and movements and could be a factor enabling the IAEA to achieve their safeguards objectives and allow for a reduction in traditional safeguards measures.

3.3.4 IAEA Cylinder-Monitoring System (for facilities safeguarded by the IAEA)

An IAEA cylinder monitoring system can support IAEA inspection activities and significantly enhance the capability to detect unregistered cylinders, material diversions, and facility misuse activities. To compile and analyze the cylinder location and status information from the registry and from on-site inspection activities, the IAEA would likely need its own cylinder monitoring system, separate from the registry, for cylinders containing safeguarded material. This IAEA cylinder monitoring system would likely consist of on-site databases at each facility and a centralized, off-site (e.g., Vienna) database. The IAEA databases would likely contain more information than the registry regarding the safeguarded material in the cylinders (e.g., specific quantities and enrichment), but the global registry would contain more general information (e.g., cylinder IDs) on more cylinders (e.g., empties, those containing unsafeguarded material in NNWSs) that might be shipped to safeguarded facilities.

Figure 2 illustrates the potential relationship between on-site IAEA databases, off-site centralized IAEA database, and the global cylinder registry at facilities within the nuclear fuel cycle. UID information would be inputted to the on-site IAEA system from unattended UID readers and/or handheld readers utilized by inspectors during the on-site inspections. The synchronization of information between the on-site databases and the centralized database would be evaluated and designed to address the detection times for the diversion and misuse scenarios. ***Note – if the centralized IAEA database were to receive location and status information directly from all cylinder handling facilities on all cylinders (not just those containing safeguarded material), there might not be a need for a separate global registry.***

A capability for the IAEA to install unattended readers at strategic operating locations in facilities would significantly increase its assurance of the absence of undeclared nuclear activities within a State through the ability to verify that only declared cylinders are being processed. Monitoring high-traffic areas where material transfers occur (e.g., feed stations) would allow for the detection of cylinders leaving the facility without having had their contents fed (and possibly diverted for clandestine production). The shorter time requirements identified for detecting cylinder diversion or facility misuse would be incorporated into the safeguards algorithms developed for the on-site databases. Safeguards algorithms would also provide "flags" or "notifications" when updated cylinder information is needed to address timely response for identifying potential material theft, facility misuse, and/or HEU production. Once proved reliable, this continuous monitoring of flow could lead to reductions in other inspection activities. The IAEA have indicated that unattended safeguards instrumentation at enrichment plants could reduce or eliminate the need for routine interim inspections.[19]

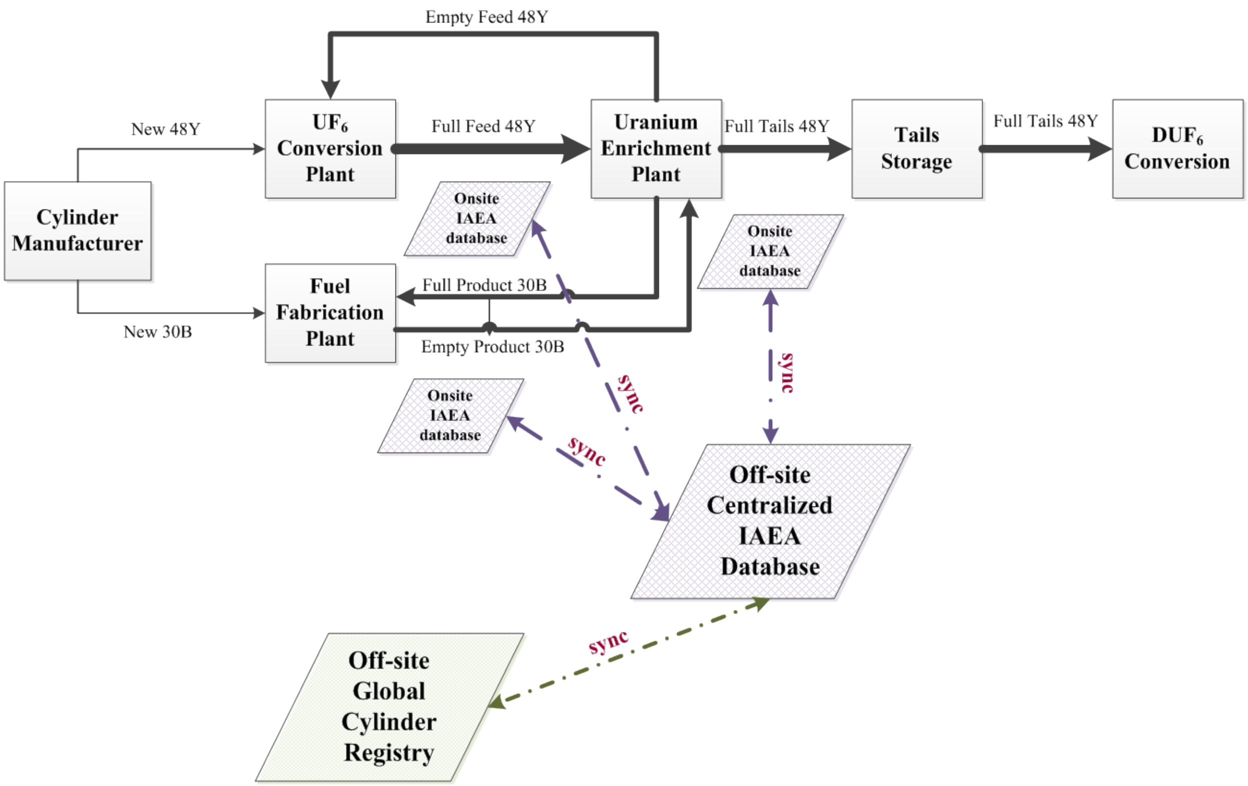

Fig. 2. Illustration of potential relationship between on-site IAEA cylinder databases, centralized IAEA cylinder database, and Global Cylinder Registry at facilities within the nuclear fuel cycle.

3.3.5 Example Application at an Enrichment Facility

Figure 3 illustrates a potential application of the global cylinder monitoring system at an IAEA safeguarded enrichment plant. The operator would have a UID reader(s) to read the UID on inbounded (received) 48Y feed cylinders and new or emptied (with heel) 30B cylinders. These cylinder receipts would be submitted to the registry within a specified time frame (e.g., 10 days). Filled and emptied cylinders would be read and reported to the registry prior to off-site shipment (emptied 48Y and full 30B cylinders) or transfer to long-term on-site storage (e.g., 48Y tails cylinders). Depending on the physical layout of the plant, the facility operator could need from one to five UID readers to perform these operations.

If the enrichment facility were subject to the IAEA safeguards, the IAEA could use portable UID readers to conduct cylinder inventories in the feed, product, and tails cylinder storage areas. Potential strategic operating locations for unattended IAEA readers include the feed stations, product withdrawal stations, tails withdrawal stations, and blending stations. Depending upon reporting times and detection times, the IAEA may desire independent UID readers at cylinder inbounding and shipping areas.

[19] E. Smith, Alain Lebrun, Rocco Labella, "Unattended Safeguards Instrumentation at Centrifuge Enrichment Plants," May 2013, 35th ESARDA Conference, Bruges, Belgium.

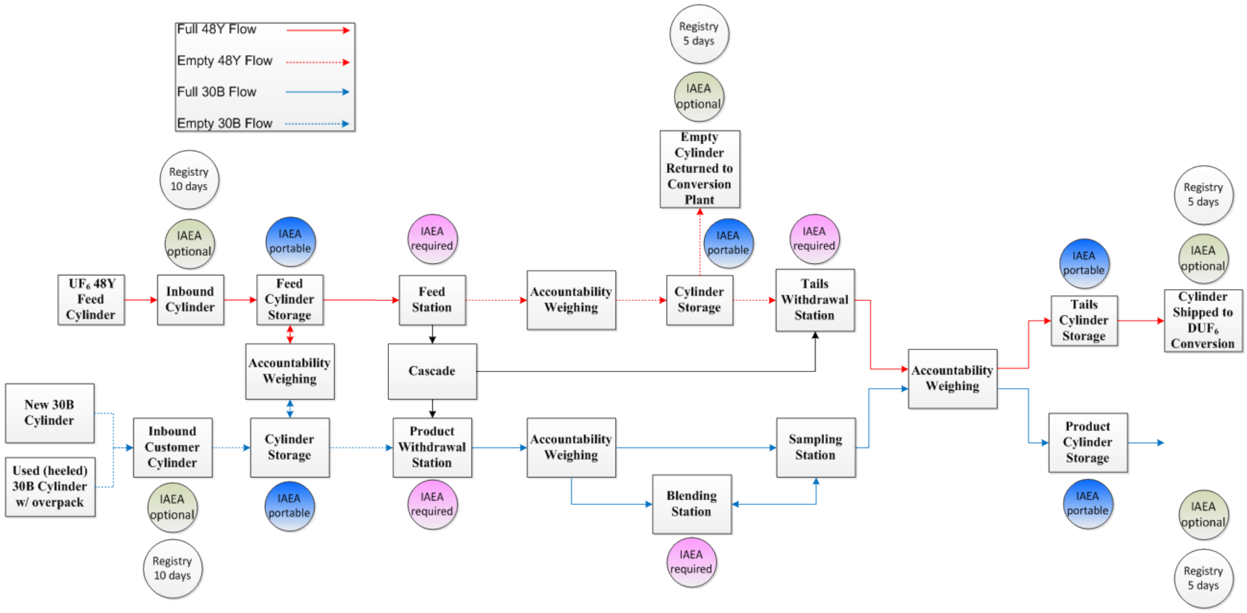

Fig. 3. Illustration of potential application of the global monitoring system at an IAEA safeguarded enrichment plant.

3.3.6 Strategy for Phased Implementation

Initially the project would focus only on model 30B and 48Y cylinders in active circulation between sites. A UID would be attached to each cylinder. While it is optimal that all cylinder purchasers use the same format/design for the identification number, it is recognized that many companies have invested resources in the format that they are currently using. Thus, initially, a limited number of well-defined identification formats may be required as the program is phased in over time.

Ultimately it would be desirable for the UID to be applied during the initial fabrication of the cylinder; this will likely require a revision to the international cylinder standards[20,21]. During a phased-in transition period, a capability to apply the UID to cylinders already in circulation would be required. It is anticipated that it would take 3–5 years to apply the UIDs to existing cylinders. Most likely, the UIDs could be applied as part of the cylinder certification process.

Incremental gains in efficiency and effectiveness could be realized even if the concept is implemented in phases:

- A standardized cylinder identification format used across the industry would improve reporting to the SSACs and the IAEA by reducing reading and transcription errors.
- A tamper-indicating, machine-readable cylinder identification could improve efficiencies in conducting cylinder inventories.
- A registry of the cylinder identification number and last reported location of all cylinders could improve timeliness in detecting the diversion of declared cylinders from sites or during

[20] American National Standard Institute, ANSI-14.1-2012: Uranium Hexafluoride Packaging for Transport.
[21] International Standards Organization, ISO-7195-2005: Packaging of Uranium Hexafluoride for Transport.

transportation and provide information to optimize scheduling of inspection and inspection activities.

- The use of unattended cylinder monitoring instrumentation at strategic operating locations could significantly improve capabilities for detection undeclared operations and could potentially reduce or eliminate routine interim inspections.

This preliminary concept of operations is being discussed with representatives of industry, national authorities, and inspectorates that could be affected by the implementation of this new concept. The preliminary concept will be revised as appropriate, taking into account feedback.

4. BENEFITS AND IMPACTS

While the primary objective of the global cylinder identification and monitoring system is to increase the international capability to detect cylinder diversion and undeclared HEU production pathways, it is recognized that implementation of any new operational or regulatory activities can have a consequence as well. The anticipated impacts and benefits for the IAEA, industry, and national regulators are described below.

4.1 IAEA

As detailed throughout the concept of operations section, the IAEA would gain increasing benefits from each component of the proposed cylinder identification and monitoring system. A standardized cylinder identification format used across the industry would improve reporting to the SSACs and the IAEA by reducing reading and transcription errors. The industry's use of a standardized format would eliminate the need for companies to apply supplemental labels and identification numbers to the cylinders that adds confusion to various reporting systems. Eliminating multiple identifiers simplifies IAEA on-site verification activities and efforts to reconcile cylinder transfers between facilities and countries.

Having a tamper-indicating UID that is acceptable to the IAEA would improve the IAEA's efficiency in verifying cylinder IDs in the cylinder yards. It can be time consuming to access and difficult to read the tiny ID number stamped on the nameplates at the end of the cylinder. A tamper-indicating UID at a more observable location would streamline this routine, repetitive inspection activity. A tamper-indicating UID would also give the inspector high confidence that the cylinder identifier has not been falsified in an effort to conceal a diversion or facility misuse, thereby enhancing the effectiveness of IAEA safeguards.

If the UID is designed to be read remotely, the time required for the IAEA to verify cylinder inventories during on-site inspections would be substantially reduced (provided that the IAEA can use their own portable UID readers during inspections). This quicker cylinder inventorying capability would increase the overall efficiency with two important benefits: 1) during normal inspections, inspectors would be able to locate and verify declared cylinders much more quickly, leaving more time for activities to detect undeclared production pathways (e.g., design verification, looking for undeclared cylinders and operations), and 2) the IAEA could verify "static" cylinder inventories more frequently than once a year during PIVs if such increased frequency was deemed necessary. Portions of the static inventories could be verified on a random basis during scheduled or unannounced inspections to address the diversion and undeclared production pathways. Additionally, this would reduce the radiation exposure of inspectors, especially in areas containing emptied cylinders.

If the IAEA were able to install unattended readers at strategic operating locations, their ability to detect the undeclared production pathways would be significantly increased by having a means to verify that only declared cylinders are being processed. Once proved reliable, this continuous monitoring of cylinders could lead to reductions in other inspection activities. This information on cylinder locations (at the facility level) will allow the identification of cylinders that should have arrived at a facility but have not, giving the IAEA an enhanced capability to more quickly detect diverted cylinders. Monitoring a high traffic area like the feed station will allow for the detection of cylinders leaving the facility that have not had their contents fed (which could indicate that such cylinders are being diverted for clandestine production).

A global registry could benefit the IAEA by providing it a capability to generate a list of all cylinders in the State. This information would be valuable in supporting State evaluations, developing annual inspection plans, and analyzing acquisition pathways. A registry would be especially valuable in IAEA efforts to reconcile cylinder transfers (i.e., transit matching) in a more timely manner. Depending on how frequently information is submitted to the registry and how frequently the IAEA safeguards department accesses the registry, it is possible that the inspectors could have access to cylinder receipt information prior to inspecting facilities. This information would be valuable in planning inspections (especially unannounced or short-notice random inspections) and verifying operator receipts records.

Finally, for States in which the IAEA has reached the broader conclusion, implementing a cylinder monitoring system would demonstrate transparency in regards to cylinder inventories and movements and could be a factor enabling the IAEA to achieve their safeguards objectives and allow for a reduction in traditional safeguards measures.

The potential impacts for the IAEA include investing time at the beginning to specify functional requirements as a user; establishing procedures and methodologies for using the information, approving for use, and installing portable and installed UID readers; and negotiating modifications to current safeguards practices.

The IAEA must ensure that the functional requirements being established for the UID are sufficient to meet IAEA's tamper-indicating requirements. Implementing any new safeguards methods and instruments will have time and cost implications for testing and approving for use, writing implementing procedures, training of inspectors, and long-term maintenance.

Use of portable readers would have to be negotiated with States (and facilities). Any installed instruments would require new software to be developed for processing cylinder ID information and will have to be approved for use by the IAEA and be acceptable to the host country (and facility operator). The resulting changes in the safeguards approach would have to be negotiated as well. A key aspect of the concept that must be considered is how quickly can the IAEA receive notifications—can notices be remotely transmitted off-site periodically or do inspectors have to physically visit the site to acquire the information? This aspect directly impacts the timeliness of detecting the diversion and undeclared production scenarios.

4.2 INDUSTRY

Once implemented, the UID would be expected to gradually become the standard used across all industry. The following benefits could then be realized by each participant:

- Near elimination of transcription errors
- Consistency of paperwork, administration, and reporting to authorities
- Avoidance of the need to add supplemental labels and markings on cylinders
- Quicker and less error-prone verification of declared cylinder inventory
- More rapid reading of cylinder ID numbers, with consequential saving of time and radiation dose, both to plant operators and safeguards inspectors
- Opportunity to automatically integrate cylinder ID into plant systems (operations, safety, MC&A)

While it is difficult to anticipate costs before the specific technologies are selected and proven reliable, it is desired for the individual UIDs to cost no more than $100–300 each. Currently, a new model 30B cylinder costs ~$5,000–$6,000 and a model 48Y cylinder costs ~$10,000–$12,000. The cost of the UID could be included in the purchase cost of new cylinders or could be a one-time expense in the recertifying of existing cylinders. The number of UID readers required to submit to the registry could be as few as one or two units in the cylinder receipt and dispatch area, and it is desired that these reader units be no more than $500–2000 each. The costs for the UIDs and readers would likely be borne entirely by the cylinder owner/users.

The impact during cylinder inbounding and outbounding should be quite low. The UID readers will likely need a power source and, depending upon the chosen technology, there may be concerns on transmission of data or interference with plant safety or security systems. Once installed, typical questions concerning reliability and maintenance remain. It will need to be determined whether the operator can submit directly to the registry or if the submission needs to go through the State authority.

Having the remaining components of the monitoring system could provide additional benefits:

- Increased knowledge of the location of a company's cylinders
- Reduced time to escort inspectors conducting cylinder inventories
- Fewer inquiries and investigations associated with unresolved matching of cylinder transfers

If the IAEA can install independent equipment to verify that only declared cylinders are being processed, traditional labor-intensive cylinder verification could potentially be reduced. Any new equipment would first have to be proven reliable, and the details associated with false alarms and equipment failures would also need to be demonstrated. Depending on where the equipment is installed, there can be concerns regarding the protection of sensitive, proprietary information. The facility will have to ensure that the equipment does not present safety risks to personnel or operations.

4.3 REGULATORS

National regulatory authorities could experience the following benefits:

- More accurate reporting of cylinder-related activities (e.g., fewer transcription errors)

- Less time and reduced exposure times to perform domestic inventories

- Increased effectiveness in preventing diversion of cylinders

- Increased efficiency and timeliness in matching and reconciling transfers of cylinders between facilities

- Could supplement existing domestic cylinder registries.

The regulators would need to confirm that any new format adopted for the UID would not conflict with existing regulations. The role of the national authorities in regards to submitting cylinder receipt and shipment information to the global registry would have to be determined. Any changes in the IAEA facility safeguards approaches to take advantage of the cylinder monitoring capabilities would have to be negotiated.

5. STAKEHOLDER ENGAGEMENT

Representatives from industry have been engaged throughout the project through international conferences, topical technical meetings, and individual briefings and discussions. A description of the cylinder monitoring project has been presented at a variety of international conferences meeting including the Institute of Nuclear Material Management,[22] the European Safeguards Research and Development Association,[23,24] and the International Symposium on Packaging and Transportation of Radioactive Materials[25] to reach larger audiences.

In early 2013, details of this preliminary concept of operations (Appendix E) were briefed to representatives of industry, national authorities, and inspectorates that could be affected by its implementation to solicit feedback, support, and recommendations on the path forward. As of the date of publishing, individual briefings on the preliminary concept have been conducted for the following industry stakeholders:

- Cylinder Fabricators (Worthington)
- Conversion (ConverDyn, Cameco)
- Enrichment (USEC, Urenco)
- Fuel fabrication (GNF, Westinghouse)

Additional efforts are under way to arrange briefings for Tenex, Areva, and Japan Atomic Energy Agency. The initial feedback was that all companies seemed interested in an industry-wide UID for cylinders. There were questions regarding the cost, who would apply the UID, and what would happen if the UID is destroyed or damaged. Some companies have or are looking at automated reading systems for the company labels that they create and apply to cylinders at their individual facilities. While all industry representatives expressed general agreement with the high-level functional requirements established for the UIDs, they expressed concern over the potential cost to switch from the methodologies that have proven acceptable at their respective facilities and have questioned what specific UID technology is being envisioned.

Separate discussions related to the project have taken place with a variety of national authorities, regulators, and inspectorates (IAEA, Euratom, and ABACC). Although some companies and regulators have registries for cylinders under their ownership or jurisdiction, there is concern among industry representatives over what information would be contained in the global registry and who would have access. The NNSA project team has consistently received valuable feedback from candid discussions with cylinder-handling stakeholders throughout the project. This feedback is being incorporated into the concept of operations as it continues to evolve.

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[22] B. Boyer, M. Whitaker, J. White-Horton, K. Durbin, "Next Generation Safeguards Initiative: Overview and Policy Context of UF_6 Cylinder Tracking Program," LA-UR-12-22810, INMM Annual Meeting, Orlando, FL, July 2012.

[23] K. Durbin, M. Whitaker, E. Wonder, "Overview of Next Generation Safeguards Initiative UF_6 Cylinder Monitoring Program," 35th ESARDA Conference, Bruges, Belgium, May 2013.

[24] M. Whitaker, J. White-Horton, K. Durbin, "Preliminary Next Generation Safeguards Initiative Concept of Operations for a Cylinder Monitoring System," 35th ESARDA Conference, Bruges, Belgium, May 2013

[25] J. White-Horton et al., "Global Identification and Monitoring of UF_6 Cylinders," PATRAM Conference, London, England, Oct 3–8, 2010.

6. NEXT STEPS

In defining the baseline requirements and developing the preliminary concept of operations, the project team has been careful to not "jump to a solution" by pre-selecting a particular UID technology (e.g., barcode, radio-frequency identification device, etc.). The next project steps include investigating available technologies and down selecting options. This process will consider, among other factors, the total life-cycle costs. More work needs to be performed on designing the architecture and the operation of the global registry. A phased-implementation strategy needs to be developed and discussed. Key components and operational aspects will need to be tested and evaluated in operational settings. Throughout these next steps, engagement with key stakeholders will continue to be a priority to ensure that both concerns and desires are identified and integrated into the design.

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APPENDIX A. GLOSSARY OF KEY TERMS

APPENDIX A. GLOSSARY OF KEY TERMS

Accounting records. Set of data kept at each facility or location outside facilities (LOF) showing the quantity of each type of nuclear material present, its distribution within the facility (or LOF), and any changes affecting it.

Batch. Portion of nuclear material handled as a unit for accounting purposes at a key measurement point and for which the composition and quantity are defined by a single set of specifications or measurements. The nuclear material may be in bulk form or contained in a number of separate items. [INFCIRC/153(Corrected), para. 100]

Confirmation of transfers. Under an INFCIRC/153-type safeguards agreement, a requirement that the exporting State will make arrangements, if the nuclear material is not subject to IAEA safeguards in the recipient State, for the IAEA to receive confirmation by the recipient State of the transfer [INFCIRC/153 (Corrected), para. 94]. Further, the five nuclear weapon States (as defined by Article IX.3 of the NPT) that have a voluntary offer agreement with the IAEA have undertaken to provide the IAEA with such confirmations of transfers from non-nuclear-weapon States, as indicated in para. 2 of [INFCIRC/207].

Cylinder monitoring. A practice that provides the locations and status of UF_6 cylinders in the commercial nuclear fuel cycle.

Cylinder nameplate. An affixed plate required for pressure vessels that further identifies and displays a product's identifying information and attributes, which are defined by governing regulatory agencies and licensing codes.

Cylinder tracking. Actively following the path or trail of a UF_6 cylinder. Tracking can also follow the historical movements of an asset, as in where it has been up to where it is now. It may also map the route a cylinder follows during shipment.

Declared cylinder. A cylinder in a safeguarded facility whose contents are reported to the IAEA as part of safeguards agreements, or a cylinder in an unsafeguarded facility whose contents are reported to a State regulatory agency under domestic safeguards laws and regulations but not under IAEA safeguards.

Decommissioning. The removal of a cylinder from active use and circulation.

Depleted uranium. Uranium in which the abundance of the isotope ^{235}U is less than that occurring in natural uranium, for example, uranium in used fuel from natural uranium-fueled reactors or tails from uranium enrichment processes. In the fuel cycle, depleted uranium is nominally stored as UF_6 in 48Y or 48G cylinders.

Destruction. The act of crushing or modifying a cylinder to make it unfit for transport or the holding of UF_6.

Detection time. The time that may elapse between diversion of a given amount of nuclear material and detection of that diversion by IAEA safeguards activities.

Domestic receipt. Receipt from other material balance areas within a State, receipt from a non-safeguarded (non-peaceful) activity, or receipt at the starting point of safeguards [INFCIRC/153 (Corrected), para. 107].

Domestic shipment. Shipments to other material balance areas or shipments for a non-safeguarded (non-peaceful) activity within a State [INFCIRC/153 (Corrected), para. 107].

Enriched uranium. Uranium having a higher abundance of fissile isotopes than natural uranium. Enriched uranium is considered a special fissionable material. In the fuel cycle, enriched uranium is nominally stored as UF_6 in 30B cylinders up to the licensed limit of 5% enriched ^{235}U. It can be stored in 48Y cylinders only on-site at a facility.

Global Cylinder Registry. A centralized listing or database containing the last reported location of all UF_6 cylinders in both safeguarded and non-safeguarded facilities.

Hand-held reader. An instrument that can be carried to where cylinders are located (e.g., storage yard) and can read the UID of each individual cylinder.

Highly enriched uranium (HEU) . Enriched uranium containing 20% or more of the isotope ^{235}U. HEU is considered a special fissionable material and a direct use material. Regulations in the fuel cycle required that HEU not be stored in 48Y or 30B cylinders due to criticality concerns.

IAEA Cylinder-Monitoring System. A combination of on-site databases that collect data from portable or installed UID readers and a centralized database that is periodically synchronized with a Global Cylinder Registry. It contains programing that continually analyzes the existing data and new submissions and generates notifications when conditions associated with a potential diversion of undeclared production pathway occur.

Import and export. International transfer of nuclear material subject to IAEA safeguards into and out of a State. The responsibility for material transferred internationally is defined under paragraph 91 of [INFCIRC/153 (Corrected)] and the requirements for notification of the IAEA by the responsible States are provided under paragraphs 92–96 of [INFCIRC 153].

Inventory change. An increase or decrease, in terms of batches, of nuclear material in a material balance area [INFCIRC/153 (Corrected), para. 107].

Legacy cylinders. Cylinders that exist on-site but are not in routine circulation (e.g., cylinders of depleted material placed in long-term storage).

Low-enriched uranium (LEU). Enriched uranium containing less than 20% of the isotope ^{235}U. LEU is considered a special fissionable material and an indirect use material. In the fuel cycle, LEU is nominally stored as UF_6 in 30B cylinders up to the licensed limit of 5% enriched ^{235}U. It can be stored in 48Y cylinders only on-site at a facility.

Natural uranium. Uranium as it occurs in nature, having an atomic weight of approximately 238 and containing minute quantities of ^{234}U, about 0.7% ^{235}U, and 99.3% ^{238}U. In the fuel cycle, natural UF_6 is nominally stored in 48Y cylinders but can be stored in 30B cylinders.

Notification of transfers. Under an INFCIRC/153-type safeguards agreement, a requirement for the State to inform the IAEA of international transfers of nuclear material, equipment, and facilities.

Nuclear material accounting. Activities carried out to establish the quantities of nuclear material present within defined areas and the changes in those quantities within defined periods. Elements of nuclear material accounting include establishment of accounting areas, record keeping, nuclear material measurement, preparation and submission of accounting reports, and verification of the correctness of nuclear material accounting information.

Registered cylinder. A cylinder whose information is included in the Global Cylinder Registry.

Tamper-indicating. An attribute that gives an indication that a protected object has been accessed.

Transit matching. The comparing and correlating/matching of IAEA safeguards-related reports of shipments and receipts, foreign and domestic (in NNWSs), to ensure that nuclear material transactions are completed as declared.

Undeclared cylinder. A cylinder containing nuclear material that should be reported to the IAEA at safeguarded facilities or to a State regulatory agency at a non-safeguarded facility.

Unique identifier. An attribute of a cylinder that can be used to differentiate its identify from others.

Unregistered cylinder. A cylinder whose information is not included in the Global Cylinder Registry.

Voluntary reporting scheme on nuclear material and specified equipment and non-nuclear material. Scheme established in 1993 for the voluntary reporting by States of nuclear material not otherwise required to be reported to the IAEA under safeguards agreements, and of exports and imports of specified equipment and non-nuclear material. [INFCIRC/540(Corrected), Annex II]

APPENDIX B. DEVELOPMENT OF SYSTEM PERFORMANCE REQUIREMENTS

APPENDIX B. DEVELOPMENT OF SYSTEM PERFORMANCE REQUIREMENTS

The team subsequently identified the core requirements and, by reviewing the report from subtask 1.2, discussed how each of the requirements would help to combat a particular diversion scenario.

Table B.1. System performance requirements

Scenario	Conditions required	Time for HEU SQ	Attractiveness of material	Detection difficulty for the IAEA	Attractiveness to proliferator (low, medium, high)	Core requirement	System design feature
Divert 48Y NU from conversion plant	Source of natural feed that can be enriched	90 days–1 year (10k–25k SWU)	Low	High (Annual PIV; Interim inspections for flow verification; IAEA policy paper 18 – not all (full) cylinders subject to safeguards [SGs])	Medium (possible long time to SQ but low detection probability)	The system **should** provide notification of the absence of a declared cylinder from a facility within **90** days of its last verification	More frequent inventory
Divert 48Y NU from facility enrichment plant	Source of natural feed that can be enriched	90 days–1 year (10k–25k SWU)	Low	Medium (annual PIV; interim inspections for flow verification; declaration as part of the ICR; increased IAEA presence)	Medium (possible long time to SQ; higher detection probability at enrichment plant due to increased IAEA presence)	The system **should** provide notification of the absence of a declared cylinder from a facility within **90** days of its last verification	More frequent inventory
Divert 30B LEU from enrichment plant	Source of LEU that can be further enriched (~70% of separative work needed to produce HEU already accomplished)	<30 days	High (significantly reduces time to an SQ)	Medium (annual PIV; interim inspections for flow verification; declaration as part of the ICR; increased IAEA presence)	High (shorter time to SQ)	The system **should** provide notification of the absence of a declared cylinder from a facility within **90** days of its last verification	More frequent inventory

Table B.1. System performance requirements (continued)

Scenario	Conditions required	Time for HEU SQ	Attractiveness of material	Detection difficulty for the IAEA	Attractiveness to proliferator (low, medium, high)	Core requirement	System design feature
Divert 30B LEU from fuel fab	Source of LEU that can be further enriched (~70% of separative work already accomplished)	<30 days	High (significantly reduces time to an SQ)	High [annual PIV; Less frequent inspector presence; reliance on randomness of inspection (~20% inspection of flow)]	High (shorter time to SQ; reduced probability of detection)	The system **should** provide notification of the absence of a declared cylinder from a facility within **90** days of its last verification	More frequent inventory
Divert 48Y NU during shipment	Source of natural feed that can be enriched	90 days–1 year (10k–25k SWU)	Low	High (reconciliations approximately 1 year; shipper/receiver differences from 1 year to longer	Medium (possible long time to SQ but low detection probability)	The system **shall** provide notification if a declared cylinder has not arrived at its destination within **90** days of its ship date (it is desirable that notification be provided if arrival doesn't occur in 30 days)	Improved detection through Global Cylinder Registry transit-matching
Divert 30B LEU during shipment	Source of LEU that can be further enriched (~70% of separative work already accomplished)	<30 days	High (significantly reduces time to an SQ)	High (reconciliations approximately 1 year; shipper / receiver differences from 1 year to longer)	High (shorter time to SQ and low detection probability)	The system **shall** provide notification if a declared cylinder has not arrived at its destination within **90** days of its ship date (it is desirable that notification be provided if arrival doesn't occur in 30 days)	Improved detection through Global Cylinder Registry transit-matching

Table B.1. System performance requirements (continued)

Scenario	Conditions required	Time for HEU SQ	Attractiveness of material	Detection difficulty for the IAEA	Attractiveness to proliferator (low, medium, high)	Core requirement	System design feature
Re-feeding of LEU at an enrichment plant)	Source is present; technology is present; undeclared activity is occurring	<<30 days	High	Medium (annual PIV; interim inspections for flow verification; declaration as part of the ICR; increased IAEA presence; significant time required for environmental sampling results)	High (very short time to SQ; no transportation required; technology is present)	The system **shall** provide notification of (1) the presence of declared cylinders with an unexpected enrichment[26] in a feed station at an enrichment plant, and (2) the presence of a cylinder (30B or 48Y) whose last reported activity was at a LEU withdrawal station	Unattended cylinder reader at feed station to provide detection using registry history
Transferring the UF_6 from a declared cylinder to an undeclared cylinder	Source is present; technology is present; undeclared activity is occurring;	<30 days (enriched)	High	High (annual PIV; inconsistent practice of using seals)	High (short time to SQ; low detection probability)		No detection; increased technical difficulty (enhanced measures at feed/withdrawal(F/W) & blending stations)
Using a declared "empty" cylinder filled with undeclared material	Source is present; technology is present; undeclared activity is occurring	[<30 days (enriched); 90 days–1 year (natural)]	High (LEU); Low (natural)	High (annual PIV)	High (LEU); Medium (natural)	The system **shall** provide notification if a declared cylinder (declared to be empty)is processed (e.g. is placed in a feed station)	Unattended cylinder reader at feed station to provide detection using registry history

[26] The monitoring system is not anticipated to record the specific enrichment of the material in a cylinder, but an enrichment stratum (depleted, natural, or enriched) can be assumed based on last known operation (e.g., filling at conversion plant, placement in product withdrawal, etc.).

Table B.1. System performance requirements (continued)

Scenario	Conditions required	Time for HEU SQ	Attractiveness of material	Detection difficulty for the IAEA	Attractiveness to proliferator (low, medium, high)	Core requirement	System design feature
Reuse of a cylinder slated for decommission / destruction	Source is present; technology is present; undeclared activity is occurring	[<30 days (enriched); 90 days–1 year (natural)]	High (LEU); Low (natural)	High (annual PIV)	High (LEU); Medium (natural)	The system **shall** provide notification if a cylinder destined for destruction or decommission is placed in a feed or withdrawal station at a conversion, enrichment, or fuel fabrication plant	Unattended cylinder reader at feed station to provide detection using registry history
The presence of an unregistered cylinder in a F/W station	Source is present; technology is present; undeclared activity is occurring;	[<30 days (enriched); 90 days–1 year (natural)]	High (LEU); Low (natural)	High (annual PIV)	High (LEU); Medium (natural)	The system **shall** provide notification of the presence of any unregistered cylinder in a feed or withdrawal station at a safeguarded facility. The system **should** provide notification of the presence of an unregistered cylinder on-site upon discovery	Unattended cylinder reader at feed station to provide detection of an unregistered cylinder
The presence of an undeclared 30B or 48Y cylinder on-site	Source is present; technology is present; undeclared activity is occurring;	[<30 days (enriched); 90 days–1 year (natural)]	High (LEU); Low (natural)	High (the IAEA is not aware of its existence)	High (LEU); Medium (natural)	The system **should** provide notification of the presence of an unregistered cylinder on-site upon discovery	Provided unattended monitoring at F/W; improved probability of detection during inspection

Table B.1. System performance requirements (continued)

Scenario	Conditions required	Time for HEU SQ	Attractiveness of material	Detection difficulty for the IAEA	Attractiveness to proliferator (low, medium, high)	Core requirement	System design feature
Applying duplicate nameplates to an undeclared cylinder	Source is present; technology is present; undeclared activity is occurring	[<30 days (enriched); 90 days–1 year (natural)]	High (LEU); Low (natural)	High (the IAEA is not aware of its existence.)	High (LEU); Medium (natural)	The system **shall** provide notification if a given cylinder ID is processed at different facilities within the same time period or if processed multiple times within a facility (e.g., duplicate cylinder IDs)	Provided unattended monitoring at F/W; improved probability of detection during inspection

APPENDIX C. DESCRIPTION OF MONITORING OPTIONS AND DETAILS OF DOWN-SELECTION PROCESS

APPENDIX C. DESCRIPTION OF MONITORING OPTIONS AND DETAILS OF DOWN-SELECTION PROCESS

With the task of developing a proof-of-concept system to show to stakeholders, the team began to further review monitoring options for the system. By coupling these monitoring options with the diversion scenarios, the team was able to eliminate, or "down select," some options. The options are found below with a description of how they work, and whether or not they can prevent specific diversion scenarios. There is also a brief explanation of why certain options have been eliminated.

TRANSFERS BETWEEN STATES

Description:

In this monitoring option, any registered cylinders that are transferred between all States are reported to the Global Cylinder Registry. The major difference would be the inclusion of reports from transfers between NWSs, as currently transfers between NWSs are not reported. Registered cylinders are considered 30B and 48Y cylinders that contain nuclear material, contain only heels, or are newly manufactured, empty cylinders. Only when a 30B or 48Y is shipped from a facility to a facility in a different State must the shipment of that cylinder be reported to the global registry within 5 days. Facilities that take receipt of registered cylinders shipped from a foreign facility have 10 days to report the receipt of the cylinders to the registry. The reporting mechanism to the global registry may be controlled by the state regulatory authority (SRA). However, in the case of newly manufactured cylinders, the cylinder manufacturer will be responsible for reporting the shipment of the cylinder. Furthermore, operators of cylinder recertification facilities will be responsible for reporting the shipment and receipt of registered cylinders, while decommissioning/destruction facilities will be responsible for reporting the receipt and destruction of registered cylinders to the Global Cylinder Registry.

Diversion Scenarios Addressed:

1. Failure of a registered cylinder to arrive at a destination in another State

Diversion Scenarios Not Addressed:

1. Detection of the absence of a registered cylinder at its declared location
2. Undeclared use of a registered feed cylinder containing declared material
3. Presence of a cylinder containing enriched material in a feed station at an enrichment plant
4. Undeclared use of a registered feed cylinder containing undeclared material
5. Presence of an unregistered cylinder in a feed/withdrawal station
6. Unregistered cylinder on-site

Reason for Elimination:

While this monitoring option improves the capability to detect diversion of an entire cylinder over current practices, the option addresses too few of the credible diversion scenarios. It is likely that one of the other options will provide a greater return on investment for more stakeholders.

TRANSFERS WITHIN STATE (SITE ARRIVAL/DEPARTURE)

Description:

Like the monitoring "Transfers between States" option, this monitoring option captures transfer of registered 30B and 48Y cylinders between facilities in different States, but this option goes one step further, also capturing transfers between facilities within a State. The reporting of transfers of registered cylinders between facilities within a State would only be performed by non-nuclear weapons states (NNWSs). In this option, the reporting times for the shipment and receipt of registered cylinders remain at 5 and 10 days, respectively.

Diversion Scenarios Addressed:

1. Failure of a registered cylinder to arrive at a destination in another State

Diversion Scenarios Not Addressed:

1. Detection of the absence of a registered cylinder at its declared location
2. Undeclared use of a registered feed cylinder containing declared material
3. Presence of a cylinder containing enriched material in a feed station at an enrichment plant
4. Undeclared use of a registered feed cylinder containing undeclared material
5. Presence of an unregistered cylinder in a feed/withdrawal station
6. Unregistered cylinder on-site

Reason for Elimination:

While this option provides more information on the movement of cylinders within a State, there is no added benefit in the number of credible diversion scenarios addressed. This can be attributed to the resources available to the State adversary to falsify operations at the facilities within their State. It is unlikely that a State would divert a registered cylinder and subsequently report to the registry that the cylinder was shipped to another domestic facility because this would require falsification of registry entries for the shipment and receipt of the cylinder.

CROSSING MBA BOUNDARIES

Description:

This option would include the reporting of registered cylinder transfers between States and facilities within States (excluding NWSs). However, facility operators would also report to the Global Cylinder Registry the transfer of registered cylinders between material balance areas (MBAs) within a facility.

Diversion Scenarios Addressed:

1. Failure of a registered cylinder to arrive at a destination in another State

Diversion Scenarios Not Addressed:

1. Detection of the absence of a registered cylinder at its declared location
2. Undeclared use of a registered feed cylinder containing declared material
3. Presence of a cylinder containing enriched material in a feed station at an enrichment plant
4. Undeclared use of a registered feed cylinder containing undeclared material
5. Presence of an unregistered cylinder in a feed/withdrawal station

6. Unregistered cylinder on-site

Reason for Elimination:

By reporting the movement of registered cylinders between MBAs, the monitoring system can be used to determine if a registered cylinder was already present in the process area MBA. However, this type of information can only be pulled from a facility with more than one MBA, which is not the case for all facilities that would use these registered cylinders. Without multiple MBAs, the only information reported would be the shipment and receipt of cylinders from the facility, gaining no increased benefit over monitoring transfers between facilities within States. Furthermore, this option would only indicate that a registered cylinder crossed an MBA boundary, not that the registered cylinder actually had nuclear material filled or withdrawn.

PRESENCE AT KEY OPERATION NODES

Description:

Like previous options, this option includes the reporting of registered cylinder transfers between States and facilities within States (excluding NWSs). However, this option utilizes multiple databases in concert with the global registry. At the facility, the operator would report to the global registry the shipment and receipt of registered cylinders to their facility. The IAEA would have an on-site cylinder database that is synced with the global registry at least once a month through a centralized IAEA database that includes information relevant to safeguards that would not be present in the global registry. This update would be completed using some currently undefined IAEA mechanism (i.e., inspector visit, remotely, etc.). This on-site database would be fed by an installed reader system at key operational nodes within each facility. For a conversion plant, these key operational nodes would be at the fill station. Additional readers may be found at the inbounding/outbounding area, the storage area, and/or the accountability scales.

Diversion Scenarios Addressed:

1. Failure of a registered cylinder to arrive at a destination in another State
2. Undeclared use of a registered feed cylinder containing declared material
3. Presence of a cylinder containing enriched material in a feed station at an enrichment plant
4. Undeclared use of a registered feed cylinder containing undeclared material
5. Presence of an unregistered cylinder in a feed/withdrawal station

Diversion Scenarios Not Addressed:

1. Detection of the absence of a registered cylinder at its declared location
2. Detection of the absence of an unregistered cylinder on-site

Reason for Consideration:

While this monitoring system does not directly detect all of the diversion scenarios, monitoring the presences of cylinders at key measurement nodes does provide the capability for the Agency to detect a vast majority of the scenarios.

INVENTORY UPON DEMAND

Description:

Inventory upon demand uses the same system described above for monitoring at key operational nodes, but also includes the ability to "ping" or query all registered cylinders present at a single facility.

Diversion Scenarios Addressed:

1. Failure of a registered cylinder to arrive at a destination in another State
2. Undeclared use of a registered feed cylinder containing declared material
3. Presence of a cylinder containing enriched material in a feed station at an enrichment plant
4. Undeclared use of a registered feed cylinder containing undeclared material
5. Presence of an unregistered cylinder in a feed/withdrawal station
6. Detection of the absence of a registered cylinder at its declared location

Diversion Scenarios Not Addressed:

1. An unregistered cylinder on-site

Reason for Consideration:

This option provides the capability to detect the absence of a registered cylinder at its declared location by using some type of device that can respond to the reader. Thus, if a registered cylinder was removed from a facility storage yard, the system in this option could be used continuously or pinged at random intervals. However, this is incapable of capturing the presence of an unregistered cylinder at the facility.

Since this option incorporates an additional active component that may increase the complexity (and ultimately affect the cost), an alternative plan of monitoring of registered cylinders at key measurement nodes is also being pursued.

APPENDIX D. FUNCTIONAL REQUIREMENTS

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REGULATORY STANDARDS

The requirements for a standardized unique identifier (UID) shall not conflict with current regulatory standards (ANSI N14.1 2001/ISO 7195-2005) for cylinder nameplates; however, it may require modifications or revision of standards in the future in order to accommodate the UID.

The application of the UID should be both simple and permanent (see application of nameplate in ANSI N14.1).

UNIQUE IDENTIFIER

Design Features

- The information associated with the UID **shall** be unique to each cylinder

- The UID for each cylinder **shall be** readable at a distance (distance to be determined [TBD])

- The UID for each cylinder **shall** be tamper indicating

- The UID **should** be located on the cylinder valve end

- The UID **shall** be designed to withstand the environmental conditions to which a UF_6 cylinder is exposed

- The UID **should** cost less than $100/cylinder

- A UID **shall** cost less than $300/cylinder

- The applied UID **shall** have a minimum life expectancy of 10 years

- The applied UID **should** have a minimum life expectancy of 30 years

- The UID **should** allow maintenance, repair, replacement, updates and changes without compromising the integrity of the cylinder.

IT Requirements

- The information associated with the UID **may** be read by other stakeholders
- The UID **shall** not access or interfere with the facility’s equipment
- The UID **may** have additional IT requirements (if UID contains system information)
- The UID **shall** only be readable by authorized equipment
- The UID **shall** *only* collect the data required to implement the monitoring system

ON-SITE READER SYSTEM

The following requirements apply to on-site reader systems that would be used to collect and submit information to either the global registry or to the on-site IAEA safeguards database (if applicable).

Design Features

- The system **shall** be able to read the cylinder UID at a distance (distance TBD)
- The system **shall** be tamper indicating
- The system **shall** monitor cylinders arriving and departing the plan
- The cylinder ID and contents data **should** be logged into a registry

Facility Operational Considerations

- The system **shall** be designed to operate within the facility's operational environment
- The system **shall** not compromise site safety/security systems

Durability and Reliability

- The system **shall** be designed to withstand the environmental conditions that it will encounter at the facility
- The system **shall** have an availability of 0. 999
- The system **should** be designed to prevent single-point failure (e.g., be connected to an uninterruptible power supply)

IT Requirements

- The system **shall** be able to operate independently of the facility's network, but may interface with plant systems as appropriate
- The system **should** have the ability to transmit off-site
- The facility system **shall** be capable of synchronizing information with the centralized system
- The system **shall** utilize encryption for transmitting, receiving, and storing sensitive information

APPENDIX E. GLOBAL MONITORING SYSTEM CONCEPT OF OPERATIONS

APPENDIX E. GLOBAL MONITORING SYSTEM CONCEPT OF OPERATIONS

Note: This description was prepared in January 2013 and was provided to industry representatives prior to visits to discuss the concept. Based on the feedback received during these meetings, the concept has evolved. The current description is provided in Section 3 of the main text.

BACKGROUND

With growing global nuclear commerce, the international safeguards system continues to face increasing demands and challenges to track and verify nuclear materials. Thousands of cylinders containing uranium hexafluoride (UF_6) move around the world annually among conversion plants, enrichment plants, and fuel fabrication plants. Typically, model 48Y cylinders are used for natural uranium and model 30B cylinders are used for uranium enriched up to 5% ^{235}U. Figure E.1 is a block diagram illustrating the flow of 48Y and 30B cylinders throughout the front end of the nuclear fuel cycle.

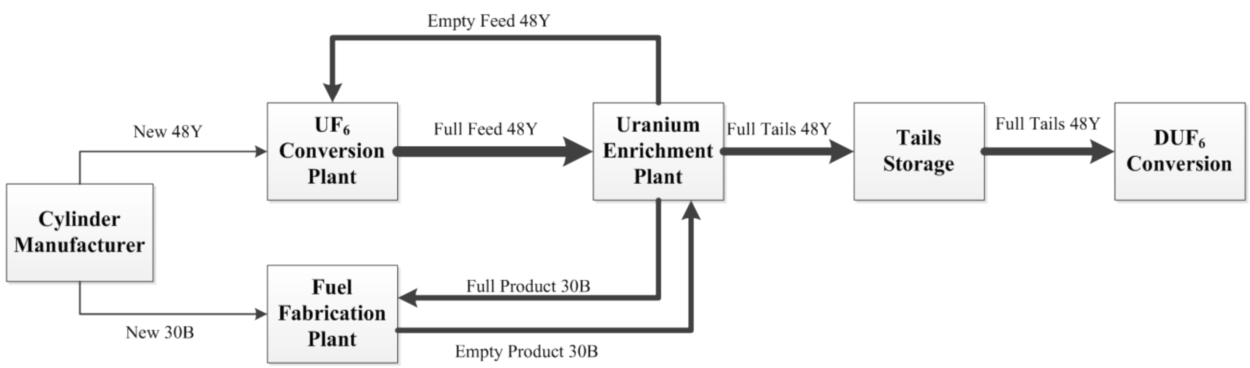

Fig. E.1. Movement of 48Y and 30B cylinders within the nuclear fuel cycle.

Because each 48Y and 30B cylinder can contain enough ^{235}U to produce two significant quantities (SQs) of Highly Enriched Uranium (HEU), they are attractive to nuclear proliferators. Both the National Nuclear Security Administration (NNSA) Office of Nonproliferation and International Security's (NA-24) Next Generation Safeguards Initiative (NGSI) and the nuclear industry have initiated steps to address their respective concerns regarding UF_6 cylinders. Additionally, leaders in the fuel cycle industry have articulated an industry rationale for developing and implementing universally a Unique Identifying Device (UID) for UF_6 cylinders to aid industry in managing, handling, and storing these cylinders in support of commercial operations.

The primary objective of the NNSA Project on Global Monitoring Uranium Hexafluoride Cylinders is to demonstrate at a proof-of-concept level the principal concepts for a global monitoring scheme that uniquely identifies the utilization of UF_6 cylinders throughout their life cycle from cradle to grave.

GLOBAL MONITORING SYSTEM OVERVIEW

A Global Monitoring System can be utilized to identify the location and utilization of UF_6 cylinders at strategic operational points, which will improve the capability of achieving the primary objectives of international safeguards regime:

- Detecting diversion of declared material (uranium)
- Detecting unauthorized activities within a State

The primary components of a Global Monitoring System include:

- a standardized, tamper indicating Unique Identifier (UID) for each cylinder
- UID readers
- Global Cylinder Registry
- IAEA Safeguards Database

Figure E.2 is a block diagram schematic of the primary components that can be utilized in a Global Monitoring System, as well as readers that may be used by the facility operators to interface with their databases that collect and use cylinder information.

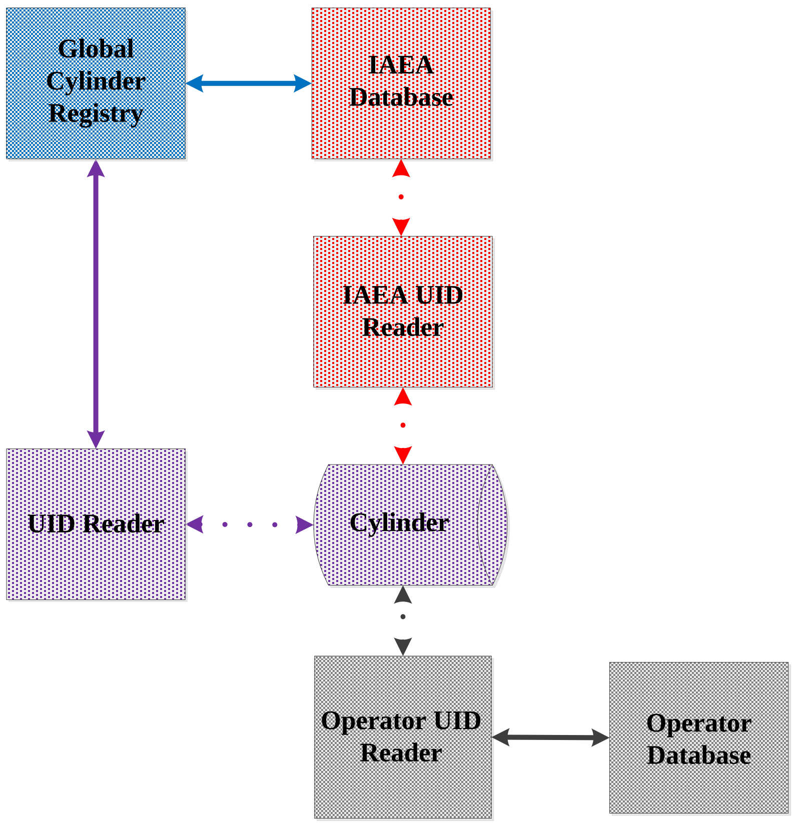

Fig. E.2. Block diagram of a global monitoring system.

Unique Identifier (UID)

The UID is the cornerstone of the Global Cylinder Monitoring System. Each cylinder will have a UID that can be used for identification and monitoring and will be designed for use across the entire UF_6 industry. The standardized, tamper indicating UID will be attached to all 30B and 48Y cylinders in both Nuclear Weapons States (NWSs) and Non-nuclear Weapons States (NNWSs). High level functional requirements for the UIDs include:

- Ability to withstand environmental conditions and cylinder handling practices
- Capability to be applied at the cylinder manufacturers and at fuel cycle facilities
- Minimum life expectancy of 10 years
- Capability to be automatically scanned or read

UID Readers

UID readers will have the capability to read the UIDs on the cylinders. These readers, both hand-held and unattended, will be used by inspectors and/or operators for the performance of tasks that include identification of cylinders and entry of cylinder information into appropriate databases. The operator will have the capability to read the UID on the cylinder and enter information into facility databases that monitor and track information related to the location, status, and utilization of cylinders. Information can also be entered into an IAEA database through the use of unattended readers, as well as hand-held readers that may be utilized by inspectors. Information can also be entered into a Global Cylinder Registry.

Global Cylinder Registry

A global registry will be established for all UF_6 cylinders (beginning with 30B and 48Y in active circulation) in both NWS and NNWS. The Global Cylinder Registry will receive inputs from operator-controlled readers and IAEA safeguards databases located at the facilities. Information captured in the Global Cylinder Registry includes, but is not limited to:

- UID
- Facility location (in-bounding and out-bounding of cylinders)
- Date
- Cylinder owner
- Status of cylinder (full, empty, material type)
- Etc.

IAEA Safeguards Database (for facilities safeguarded by the IAEA)

UID information will be input to the IAEA database from unattended UID readers and hand-held readers utilized by inspectors during the on-site inspections. An IAEA safeguards database will be utilized to support IAEA inspection activities and enhance the capability to detect unregistered cylinders, material diversions, and facility misuse activities. The IAEA system may consist of localized, on-site databases (which contain analysis algorithms) and a centralized IAEA database. Synchronization between the on-site databases and the centralized database will be required to meet detection times for the diversion and misuse scenarios. Figure E.3 provides a block diagram illustrating a potential application of an integrated IAEA system at facilities within the nuclear fuel cycle.

As noted above, some mechanism for synchronization of the information in the Global Cylinder Registry and the IAEA Centralized Database would be required. This synchronization will support the goals of detecting the diversion of nuclear material in UF_6 cylinders and the misuse of facilities.

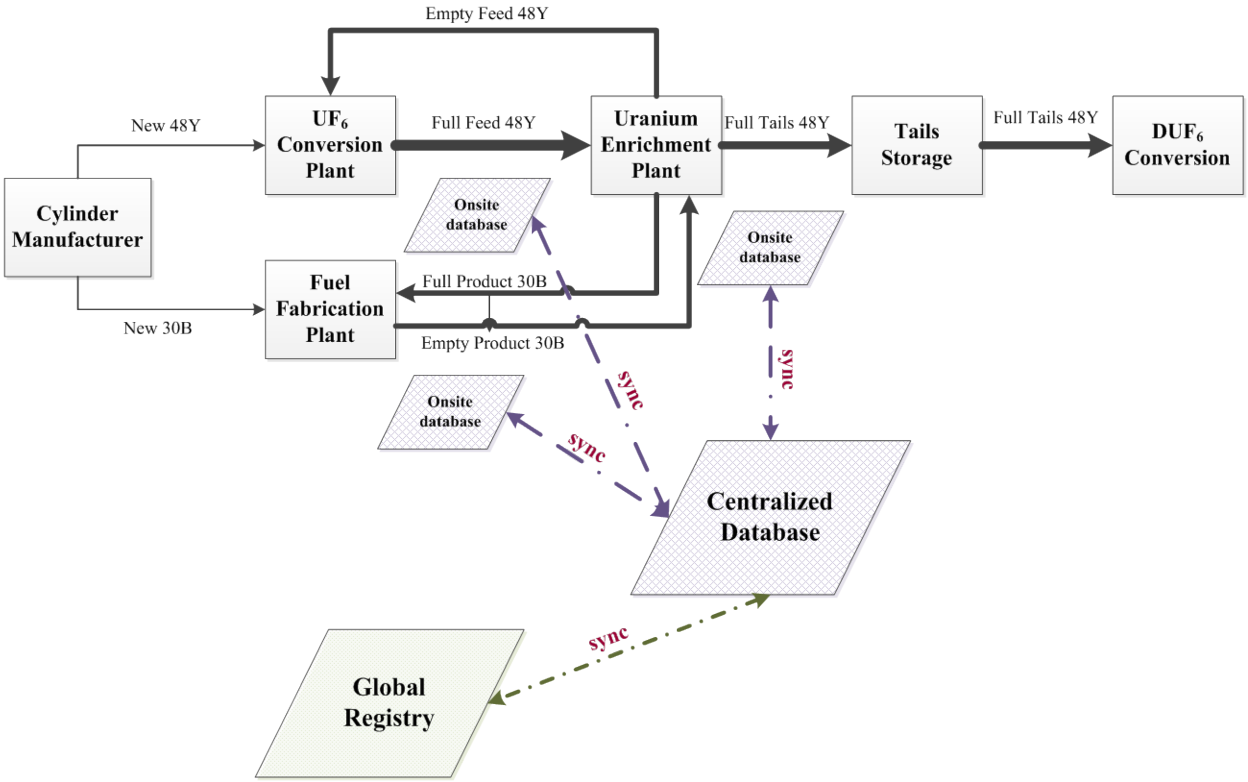

Fig. E.3. Block diagram illustration of an integrated system.

Benefits to Operators/Cylinder handlers

The following benefits could be realized with the full and successful implementation of the Global Monitoring System:

- More rapid reading of cylinder ID numbers, with consequential saving of time and radiation dose, both to plant operators and safeguards inspectors
- Avoidance of the need for operators to use ad-hoc methods to mark ID numbers on cylinders
- Consistency of paperwork, administration, and reporting to authorities
- Near elimination of transcription errors
- Quicker and less error-prone verification of declared cylinder inventory
- Increased confidence in safeguards inspectorates' matching reported shipments and receipts
- Increased knowledge of the location of a company's cylinders
- Can be integrated into plant systems (operations, safety, MC&A)

Benefits/Impacts to the Regulator(s)

The following benefits could be realized with the full and successful implementation of the Global Monitoring System:

- Increased efficiency in performing cylinder inventories during inspections to detect diversion of cylinders
- An improved capability for safeguards inspectors to assure that no undeclared UF_6 is present at a facility
- Provides a new capability to detect the misuse of facilities for undeclared production
- Increased efficiency and timeliness in matching and reconciling transfers of cylinders between facilities

NEXT STEPS

- Engage stakeholder in discussions on the concept of operations for a Global Cylinder Monitoring System
- Investigate available technologies for a standardized UID and reader systems
- Define the Global Cylinder Registry (e.g., data, data handling, architecture)
- Develop a phased implementation strategy for evaluation
- Estimate costs and evaluate life-cycle cost benefit.