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Next Generation Safeguards Initiative: Overview and Policy Context of UF_6 Cylinder Tracking Program

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ABSTRACT

Thousands of cylinders containing uranium hexafluoride (UF_6) move around the world from conversion plants to enrichment plants to fuel fabrication plants, and their contents could be very useful to a country intent on diverting uranium for clandestine use. Each of these large cylinders can contain close to a significant quantity of natural uranium (48Y cylinder) or low-enriched uranium (LEU) (30B cylinder) defined as 75 kg ^{235}U which can be further clandestinely enriched to produce 1.5 to 2 significant quantities of high enriched uranium (HEU) within weeks or months depending on the scale of the clandestine facility. The National Nuclear Security Administration (NNSA) Next Generation Safeguards Initiative (NGSI) kicked off a 5-year plan in April 2011 to investigate the concept of a unique identification system for UF_6 cylinders and potentially to develop a cylinder tracking system that could be used by facility operators and the International Atomic Energy Agency (IAEA). The goal is to design an integrated solution beneficial to both industry and inspectorates that would improve cylinder operations at the facilities and provide enhanced capabilities to deter and detect both diversion of low-enriched uranium and undeclared enriched uranium production. The 5-year plan consists of six separate incremental tasks: 1) define the problem and establish the requirements for a unique identification (UID) and monitoring system; 2) develop a concept of operations for the identification and monitoring system; 3) determine cylinder monitoring devices and technology; 4) develop a registry database to support proof-of-concept demonstration; 5) integrate that system for the demonstration; and 6) demonstrate proof-of-concept. Throughout NNSA's performance of the tasks outlined in this program, the multi-laboratory team emphasizes that extensive engagement with industry stakeholders, regulatory authorities and inspectorates is essential to its success.

INTRODUCTION

With growing nuclear commerce and new verification mandates, the international safeguards system continues to face ever-increasing demands to track and verify nuclear materials. Figure 1 charts out the nuclear fuel cycle and we can see that a State having the capabilities of making low-enriched uranium has many of the components necessary for making a weapon. Emerging proliferation threats from both State and non-State terrorist actors are also leading to increased concerns over the diversion of nuclear materials—for example, the loss during transport of cylinders containing UF_6 or the introduction of undeclared fuel into enrichment plants. The most commonly used cylinders for transporting, processing, and storing UF_6 are the model 48Y cylinder which typically contains up to ~8,500 kg U of natural uranium and the model 30B cylinder which typically contains up to ~1,500 kg U of LEU (ranging from 3-5% enriched in ^{235}U). Each of these cylinders can contain almost one significant quantity (SQ) of LEU defined as 75 kg of ^{235}U in uranium. Assuming a clandestine enrichment facility with a capacity of 10,000-25,000 SWU/year, one cylinder containing natural uranium is enough material to produce a SQ of HEU at 90% enrichment levels, defined as 25 kg of ^{235}U in uranium, in ~ 3 months to 1 year. A cylinder containing LEU (~3-5% enriched) is enough material to produce a SQ of 90% enriched HEU on ~30-90 days. Currently, the IAEA detection timeliness goals for detecting diversion are one year for indirect use material such as LEU and one month for unirradiated direct use material such as HEU.

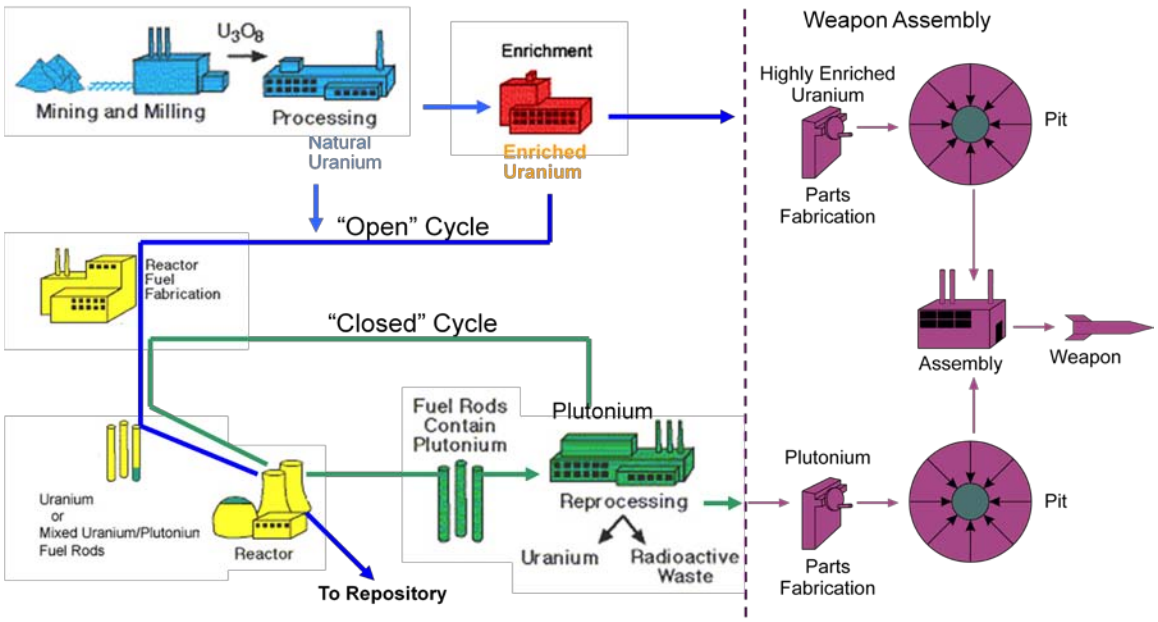

FIGURE 1: The Nuclear Fuel Cycle Showing Civil and Military Overlap

Both the National Nuclear Security Administration (NNSA) Office of Nonproliferation Next Generation Safeguards Initiative (NGSI) and the nuclear industry have begun taking steps to address their respective concerns regarding UF_6 cylinders.[1] A NGSI study done in 2009 identified the perceived key international safeguards challenges associated with the risk of State diversion of loaded UF_6 cylinders.[2] The NNSA subsequently sponsored a workshop at Savannah River National Laboratory in May 2010 at which participants from several DOE national laboratories discussed potential actions to address the challenges in developing a system for global monitoring of UF_6 cylinders.[3] The NNSA also sponsored a survey of industry stakeholders in UF_6 cylinder manufacture and usage.[4] In parallel, several leaders in the nuclear fuel cycle industry have articulated an industry rationale for developing and implementing universally a UID for UF_6 cylinders to aid industry in managing, handling, and storing these cylinders in support of commercial operations. Identifying and tracking these cylinders has also been discussed at international meetings, including a Packaging and Transport of Radioactive Materials (PATRAM) workshop in October, 2010.[5] Both Global Nuclear Fuel - Americas[6] and Urenco[7] published and presented papers at the 2011 INMM Annual meeting. Furthermore, a working group in the Institute of Nuclear Materials Management (INMM) is starting to examine the issues in developing an industry-wide standard for a UID for UF_6 cylinders.

PROGRAM DESCRIPTION

NNSA's cylinder tracking program plan identified the principal elements of a 5-year program to demonstrate, at the proof-of-concept level, a UF_6 cylinder identification and monitoring system. If successful, this system could provide an integrated solution to meet both industry needs for uniquely identifying cylinders to improve cylinder operations and challenges facing international safeguards against diversion of low enriched uranium and undeclared enrichment. The program plan builds upon prior discussions with industry leaders, cylinder users, and international safeguards experts including the IAEA, EURATOM and select State Systems of Accounting and Control (SSACs), and implements recommendations from previous national laboratory studies sponsored by NNSA and workshops on UF_6 cylinder issues. The program plan also builds on previous and ongoing industry engagement with Urenco, United States Enrichment Corporation, and Global Nuclear Fuel - Americas.

The ultimate objectives of the program are to achieve a proof-of-concept demonstration for a unique identification system. The 5-year timeframe takes into account the anticipated time needed for the views of various stakeholders to coalesce on what elements of the current problem set, resulting from the absence of any uniform tracking, monitoring, or identification system for cylinders, can or should be addressed through the development of such a system. This timeframe also allows for the adaptation of monitoring technologies to meet specific operational challenges, and for the development of a UID database, a critical tool for cataloguing and accounting for UF_6 cylinders.

The program has six principal, top-level tasks: 1) define the problem and establish the requirements for a unique identification (UID) and monitoring system; 2) develop a concept of operations for the identification and monitoring system; 3) determine cylinder monitoring devices and technology; 4) develop a registry database to support proof-of-concept demonstration; 5) integrate that system for the demonstration; and 6) demonstrate proof-of-concept. Engaging significant stakeholders to arrive at a consensus on the program's direction and path forward, culminating in the demonstration of proof of concept, will be fundamental to program success.

TASK 1: BASELINE PROBLEM DEFINITION AND REQUIREMENTS FOR A UNIQUE IDENTIFICATION AND MONITORING SYSTEM (SEPTEMBER 2011-MAY 2012)

Developing and documenting the institutional, informational, technological, and operational challenges that a cylinder identification and monitoring system should meet in addressing industry and cylinder-related safeguards needs provides a foundation for the requirements that will shape the monitoring concept that will be demonstrated at the end of the program. Developing these foundation requirements will be achieved through five subtasks.

Subtask 1.1: Document "life of a UF_6 cylinder"

The first key subtask develops a detailed understanding of the "life of a cylinder" through a pathway analysis that includes cylinder manufacture and procurement processes; cylinder handling and operational practices at conversion, enrichment, and fuel fabrication facilities, as well as related transportation and storage; and, finally, cylinder retirement/disposal practices. Figure 2 below shows this "subset" of the fuel cycle for the use of UF_6 and cylinders.

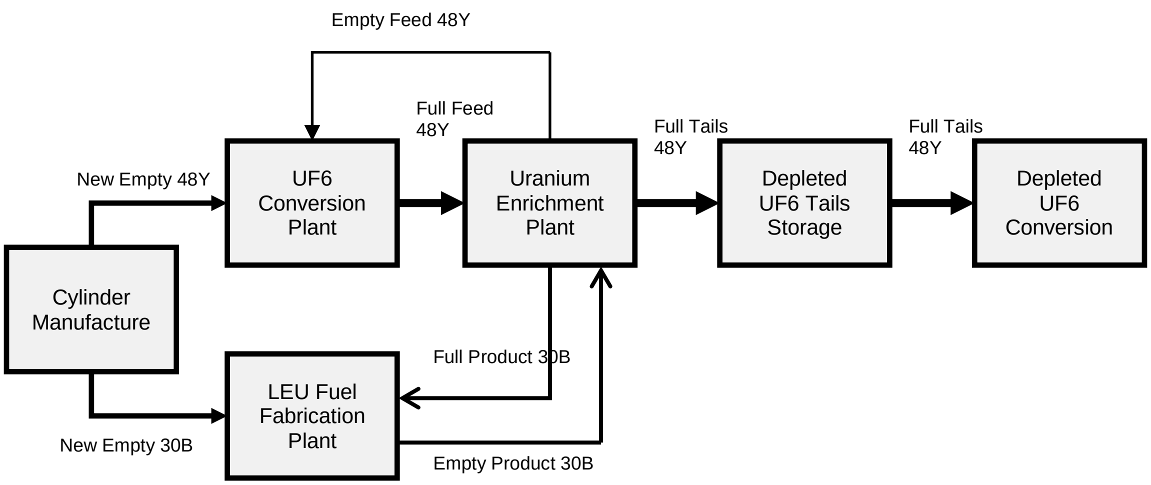

FIGURE 2: UF_6 Cylinder Nuclear Fuel Cycle Life Cycle

The study identified information that is most important for monitoring UF_6 cylinders from cradle-to-grave in order to understand and meet the requirements of stakeholders throughout the nuclear industry. It defines the operational and handling practices that comprise the operational environment within which a cylinder identification and monitoring system must operate. The life of a cylinder analysis shows how this can readily be achieved. This subtask integrates industry perspectives of needs and feedback from industry stakeholders. Active project team engagement of industry stakeholders will provide this information and guidance.

Subtask 1.2: Identify UF_6 cylinder diversion and undeclared production pathways

The pathway analysis in the life of a cylinder subtask supports identifying and describing pathways for State diversion of cylinders during the UF_6 cylinder lifespan and identifies opportunities for the use of undeclared cylinders to produce undeclared material. The pathway analysis was overlaid on the cylinder lifecycle report to ensure consistency of assumptions and information with the task and assure comprehensive analysis that covers pathways at all points in the life of a cylinder. The diversion scenarios developed in this subtask are being incorporated in Task 2 into the concept of operations for a system and how it would address the scenarios. The project team will engage other organizations and parties, as appropriate, when looking at this problem, to leverage their work and avoid duplication of effort. Figure 3 has an example of the diversion pathways developed in this task with the example being a diversion of a 30B product cylinder for clandestine enrichment. Task 2 attempts to address all of the viable diversion paths for 30B and 48Y cylinders used in conversion and enrichment facilities.

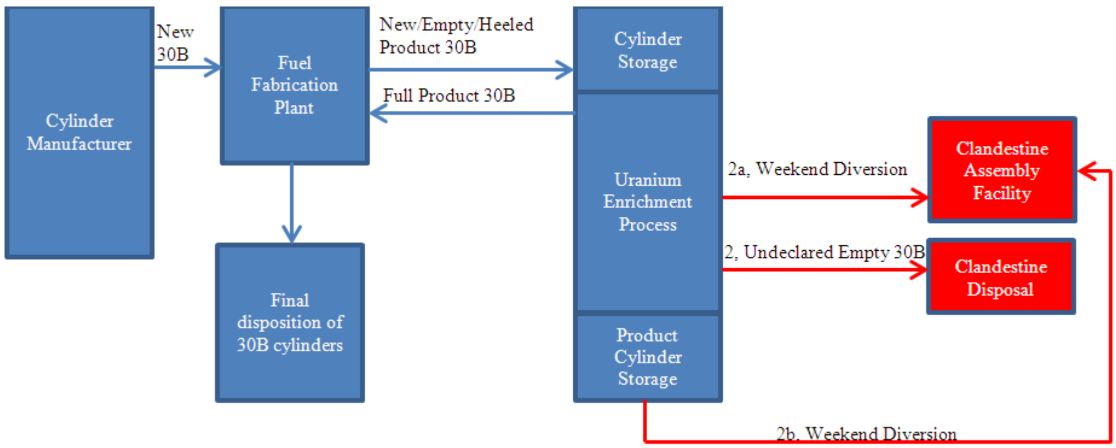

FIGURE 3: Pathway for Using a 30B Product Cylinder for Clandestine Enrichment

Subtask 1.3: Identify international methods of detecting diversion and use of undeclared UF_6 cylinders

Mechanisms for detecting the intentional diversion of UF_6 cylinders by a State are inherently challenging to develop due to a lack of consistent approaches to identifying cylinders, issues for international safeguards purposes in transit matching and timeliness of reporting of receipts and deliveries, and other factors that were identified in the initial 2009 study.[3] The team took into account that the majority of enriched uranium is produced, converted, or enriched in Nuclear Weapon States (NWS) and that the material may not actually be placed under IAEA safeguards until it reaches a destination in a Non-Nuclear Weapons State (NNWS) country. The project team identified methods of detecting diversion under current IAEA safeguarding practices; deficiencies in detection that should be remedied by a UID/monitoring system; elements of potential monitoring system approaches to address these deficiencies; and remaining detection issues that were not addressed through the proposed approach but that nonetheless might merit some sort of response and future actions.

Subtask 1.4: Engage major stakeholders (Industry, SSAC, and IAEA)

Major stakeholders must be engaged to develop a detailed understanding of the problems facing current cylinder identification and monitoring practices. Of perhaps equal importance, however, is gauging these stakeholders' recognition of the potential proliferation risks and their respective tolerances for operational and resource impacts. A simple correlation between cylinders and material can be translated into efficiency improvements, dose reduction, and reduced human errors for each UF_6 cylinder moved or verified. A concept that moves beyond this to include some form of monitoring, or ultimately physical tracking, will likely require considerable effort to develop stakeholder support. Implementing any change in nuclear material monitoring practices supporting international safeguards will include carefully managed engagement with the IAEA Division of Concepts and Planning, Division of Technical Support, and the three operations divisions so that the concept, the technology and the field implementation, respectively, will be integrated properly across the IAEA. Hence, IAEA-approved equipment and techniques will be critical to the success of a global monitoring program. Most SSACs that implement international safeguards at the national level have taken steps to standardize national accounting systems in order to meet IAEA reporting requirements. Accommodating a UF_6 monitoring system will affect the type and frequency of information reported by SSACs to the IAEA. As there will be domestic implications in the U.S. with a UF_6 monitoring system, the project team is also coordinating with the U.S. Nuclear Regulatory Commission (NRC).

Subtask 1.5: Work with the industry to develop an international standard for a UID

This task started by reviewing the standards for cylinder construction and operation to see what information is presently affixed to a cylinder and what information the project team believes essential and desirable for the cylinders to carry. In particular, the project team is engaging industry working groups to develop a new American National Standards Institute (ANSI) and International Organization for Standardization (ISO) standards for unique identifiers for cylinders, and participate in and support the working group as appropriate. It is essential that this standard for unique identifiers and methods of affixing the identifier to cylinders support the overall monitoring concept. Task 1 assumes that the industry group or groups working through the Institute of Nuclear Materials Management to develop a UID and developing an international technical standard for incorporating UIDs into all new UF_6 cylinders will develop a UID standard that the project team will incorporate in its proposed proof-of-concept demonstration.

TASK 2: DEVELOP CONCEPT OF OPERATIONS FOR AN IDENTIFICATION AND MONITORING SYSTEM (MAY 2012-DECEMBER 2012)

The second principal task is to develop a unique identifier and monitoring concept that will meet stakeholder needs and that will be demonstrated at the end of the proposed program. Developing a full concept of operations that will include all principal institutional, information and technology elements and related performance requirements, implementation models, and roles and responsibilities of all stakeholders will be the goal of Task 2.

Subtask 2.1: Establish functional requirements and corresponding key concept components and implementation approaches

This subtask will develop an integrated set of functional requirements of what the system concept must do, the principal elements of the concept that address these requirements, and associated performance requirements/metrics, and the implementation requirements for each element of the concept. The baseline analysis identified the functional needs, problem sets to be addressed, and stakeholder interests. This subtask will define the parameters for a conceptual cylinder identification and monitoring system that addresses these needs, and will translate the findings from Task 1 into functional requirements for the concept. Functional information requirements must address possible diversion and clandestine nuclear material production scenarios as well as potential gaps in IAEA verification methods. The functional requirements will identify routine verification activities suited to minimize dose, reduce transcription errors and increase efficiency in identifying UF_6 cylinders at a site, facility or location outside a facility.

Subtask 2.2: Develop concepts(s) for a monitoring system

Based on the preceding tasks, this subtask will develop the concept that will be demonstrated at the end of the 5-year program. Several options for the level of monitoring should emerge based on geography—e.g., inside the facility; within a specific State; global; and on time—e.g., real-time vs. after-fact interrogation of UIDs at sites. Working closely with stakeholders, the project team will select the monitoring approach, integrating the UID concept that might be established by working groups involving operators of facilities that use UF_6 cylinders. This decision, in turn, will be of fundamental importance to defining the scope of the technology development requirements addressed in Task 3.

The UID concept developed for use by industry will require physically affixing the UID to the cylinder such that the UID is physically robust, tamper-indicating, and spoofing-proof. This subtask will identify any such near-term adaptive Research & Development (R&D) that might be necessary to meet these requirements. For purposes of the demonstration, commercial- and government off-the-shelf (COTS) and (GOTS) technologies will be employed as much as possible to save costs and standardize implementation.

Subtask 2.3: Define full concept of operations for the recommended monitoring concept

This subtask will build on its predecessors to define a full concept of operations for an end-to-end demonstration at a proof of concept level of key functions, information management and cylinder registry database, cylinder identifier, cylinder handling, transport, and storage operations, and implementation responsibilities of all key system elements of the concept. This concept of operations is critical to ensure that the demonstration will achieve its objectives of providing confidence that further development and deployment will be warranted, and that no unintended negative consequences or performance gaps or risks exist.

Subtask 2.4: Preliminary cost/benefit analysis

Based on what is learned in Task 1 and Subtasks 2.1-2.3, a preliminary cost/benefit analysis will be completed to support the “off-ramp” decision identified below that will follow completion of Task 2.

TASK 3: DETERMINE CYLINDER MONITORING DEVICES AND TECHNOLOGY (MARCH 2013-MARCH 2014)

The third major task is to select applicable currently available technologies to support the demonstration, and to identify areas where longer-term R&D could enhance the effectiveness and cost-efficiency of cylinder monitoring should the project proceed forward after completion of the proof of concept demonstration. The operational requirements for reliability, ruggedness, resistance to environmental extremes, portability, and data authentication identified in Task 1 will provide screening criteria to evaluate candidate technologies. A thorough survey and study to examine overall strengths and weaknesses of candidate equipment and technologies in various transportation scenarios will identify existing and emerging technologies and any adaptive development needed for specific application to cylinders.

The proof of concept demonstration will leverage current commercial and government programs to develop and employ tracking/monitoring technologies. Development work should be incremental in nature to adapt one or more such technologies for use in the demonstration. The ultimate system deployed might well integrate the results of additional longer-term R&D that is indicated as necessary to provide full functionality and meet performance requirements for the full-up system.

TASK 4: DEVELOP REGISTRY DATABASE TO SUPPORT PROOF OF CONCEPT DEMONSTRATION (JUNE 2013-JUNE 2014)

One of the key goals of the project team is to create a registry database to capture the unique identification information for the cylinders and extract vital information for international safeguards purposes. It will be important to identify an entity to manage the information and determine which stakeholders need access to specific cylinder data. Information gathered during movements along the cylinder life cycle pathway could be used by industry, SSACs and the IAEA to establish or confirm a cylinder's location. Authentication of data uploaded to the registry from the monitoring device is necessary to ensure the absence of data tampering or falsification. Industry proprietary information will need to be isolated and protected at the appropriate level in order to allow monitoring of UF_6 cylinders as they are transported around the globe.

Advantages and disadvantages of sifting through which information should be available to the industry, SSAC and IAEA will be considered in a gap analysis study. Since determining required registry information is dependent on stakeholder, policy and technically-driven decisions, the gap analysis will define aspects of each of the user's needs. As the program matures the project team will resolve the challenge of data registry architecture design.

TASK 5: SYSTEM INTEGRATION FOR THE DEMONSTRATION (APRIL 2014-SEPTEMBER 2015)

This task will integrate the results of the previous tasks and establish final performance goals for the proof of concept demonstration, and integrate all system components into the system to be demonstrated. The final performance objectives will provide the basis for the demonstration task budget and timeline for the accomplishment of specific goals and objectives. The project team will engage all stakeholders to achieve consensus on the system performance goals to be demonstrated.

The project team will integrate all components to be demonstrated in the proof of concept demonstration, including technology components, registry data base, and implementation responsibilities.

TASK 6: DEMONSTRATION OF PROOF OF CONCEPT (OCTOBER 2015 – APRIL 2016)

The final task is the actual demonstration of the proof of concept. Based on analysis of results of the demonstration, the project team will propose a path forward for a follow-on development and deployment strategy. NA-24 will make a go/no-go decision on this proposal following the demonstration of the proof of concept.

STAKEHOLDER ENGAGEMENT

There are multiple stakeholders in the development of a cylinder tracking system, including cylinder manufacturers, nuclear industry facilities that use and handle cylinders, cylinder transporters, the IAEA, and national regulatory agencies. Extensive engagement with these stakeholders is a critical element of this program, and their cooperation throughout the system's implementation will be essential to its success.

Examples of this engagement include a presentation by representatives from NNSA, IAEA, and Urenco on a concept for a world-wide system for identifying UF_6 cylinders in 2009,[8] an operator's perspective from an evaluation of a UF_6 cylinder RFID evaluation,[6] Urenco's position on standardizing identification of UF_6 cylinders,[7] and a NNSA-sponsored workshop on cylinder identification.[9] Urenco has been an important partner in this activity championing the idea of a global cylinder database that would be useful for their operations and for safeguards and security endeavors. As noted above, we are also coordinating with the U.S. NRC for domestic and international support in the U.S.

STATUS

Although the program runs for five years, it has the requirement that studies and reports be completed to set the stage for the next task throughout the project. Reports from the subtasks associated with Task 1 are complete and are being reported at this meeting. The project team has begun the Task 2 efforts with the goal of completion by the end of calendar year 2012.

CONCLUSION

Completion of this 5-year program provides the foundation for follow-on efforts to implement the UF_6 identification and monitoring system on a universal basis. Additional technology development, stakeholder engagement, and institutional development must surely be needed to accomplish this broader objective. Consistent with the notion of demonstration at the proof of concept level, key elements of such a system could be included in the demonstration, but possibly not be in the scope of the final system in deference to the finalized needs of industry, government and international inspectorates.

A successful demonstration of the proof of concept should provide a foundation for decisions on the follow-on effort to achieve a universally implemented system, and commitment of resources by a wide range of stakeholders needed to accomplish the ultimate objective. Engagement of international stakeholders, i.e. cylinder manufacturers, facilities, IAEA, and regulating bodies such as the U.S. NRC is essential to the immediate progress and acceptance of the program. The stakeholders must be informed of the system's benefits, which can be communicated in terms of efficiency improvements, radiation dose reduction and minimizing errors for each UF_6 cylinder moved or verified.

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