

# **MANAGEMENT OF ACCOUNTABLE NUCLEAR MATERIAL**

## ***The U.S. Nuclear Materials Management and Safeguards System***

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### **Abstract**

The Nuclear Materials Management and Safeguards System (NMMSS) is the U.S. Government's national level system for tracking and accounting for domestically held source, special, and other accountable nuclear material and for tracking imports and exports of these materials to and from the U.S. The system tracks various other U.S. Department of Energy (DOE)-owned nuclear materials for financial, materials management, and safeguards purposes. NMMSS plays an indispensable role in the DOE's nuclear material management processes and overall implementation strategy. This paper will present the process by which in collaboration with DOE/NNSA sites, program offices, and regulated commercial nuclear industry licensed by the NRC, these objectives are met. Furthermore, this paper presents lessons learned, and recommendations of potential benefit for other International Atomic Energy Agency (IAEA) member states using similar materials control and accounting systems.

### **1. Introduction**

The Nuclear Materials Management and Safeguards System (NMMSS) serves as the accountancy arm of the U.S. State System of Accounting for and Control (SSAC) of nuclear material. NMMSS receives reporting from possessors of accountable nuclear material on their inventories, transactions, and accounting, and maintains the quality-controlled information in a central data system for use by U.S. government and other designated parties. NMMSS contains information on both government-owned and privately held material used for national security and commercial purposes. This paper focuses on the use of NMMSS for accounting of government-owned nuclear material.

Most of the U.S. government-owned material is held by the Department of Energy (DOE) and its semi-autonomous agency, the National Nuclear Security Administration (NNSA). Within the NNSA, NMMSS is operated by the Nuclear Materials Integration Division (NMID) in the Office of Environmental, Safety, and Health (ESH). The U.S. Nuclear Regulatory Commission (NRC) provides financial and technical support to NMMSS for the management of information on nuclear material at its licensees in the commercial sector.

The material accountancy information in NMMSS serves multiple purposes for the U.S. government. NMMSS records are used to meet U.S. commitments to the International Atomic Energy Agency (IAEA) under multiple safeguards agreements with the IAEA. NMMSS also tracks commercial material obtained from foreign suppliers under bilateral and multilateral Nuclear Cooperation Agreements, which constrain the end use of material. DOE and NNSA decisionmakers use NMMSS information on government-owned material in allocating material to support national policy, both for defense and national security as well as support for commercial production of nuclear energy. Maintaining high quality material accountancy data in NMMSS is thus critical for informed decision making.

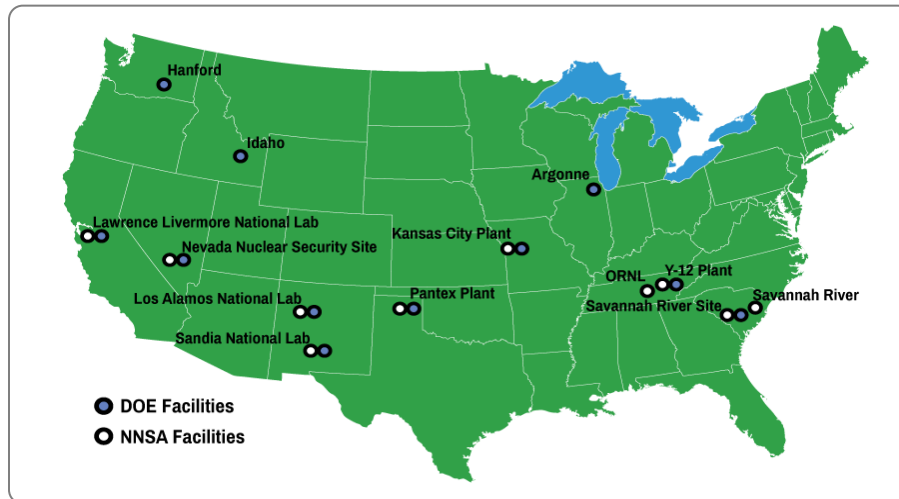
## 2, Discussion

### 2.1 DOE Accountable Material Reported to NMMSS

Material held at DOE sites (Figure 1) is subject to the DOE framework for accountable material as given in a series of Orders, Standards, and Handbooks. Specifically, DOE Order 474.2A identifies the types of accountable material at DOE facilities [1]. The update to this Order in 2023 reorganized the material type information and provided explicit definitions of terms. The Accountable Material designated in this Order falls into three categories:

- Special Nuclear Material
- Controlled and Accounted for as Special Nuclear Materials
- Other Accountable Nuclear Material

Special Nuclear Material (SNM) follows the definition in the U.S. Atomic Energy Act to encompass plutonium and uranium enriched in uranium-235 or uranium-233. The second category covers specific isotopes of Americium and Neptunium. The third category includes source materials (Thorium, normal and depleted Uranium), as well as Curium, Deuterium, Tritium, and enriched Lithium.



**Figure 1:** Major DOE-operated facilities subject to material accountability.

The different categories of material have different protection strategies. The DOE Order applies a graded approach to control and accounting for its accountable material, based on material type, quantities, and attractiveness, similar to the approach used for physical security.

The system for reporting to NMMSS by DOE sites uses codes for each of the accountable material types [2]. The material type codes include designations for broad material types (e.g., enriched uranium) and more specific codes for more granular description (e.g., codes for different enrichment levels).


Government-owned material at facilities regulated by the NRC is subject to NRC regulations. The NRC requirements for reporting of accountable material are given in Chapter 10 of the Code of Federal Regulations (10 CFR), primarily 10 CFR Part 74, “Material Control and Accounting.” NRC has further guidance documents for reporting transactions and inventory information to NMMSS by its licensees [3], including directions for government-owned material. NRC requirements for material

control, accounting, and physical protection also follow a graded approach very similar to the DOE framework.

Figure 2 shows the accountable material under DOE and NRC jurisdictions. NRC regulations have a more limited set of materials subject to material control and accounting requirements than the DOE Order. Accountability under NRC regulations apply to special nuclear material and certain source material; inventories and transactions of the other nuclides tracked by DOE are not required to be reported.

**Nuclear Material Reporting Units and Characteristics**

Name of Material	MT Code	Reporting Weight Unit Report to Nearest Whole Unit	Element Weight	Isotope Weight	Isotope Weight %	Material Type Category
Depleted Uranium	10	Whole Kg	Total U	U-235	U-235	Source
Enriched Uranium	20	Whole Gm	Total U	U-235	U-235	Special
Plutonium-242	40	Whole Gm	Total Pu	Pu-242	Pu-242	Other
Americium-241	44	Whole Gm	Total Am	Am-241	-	Other
Americium-243	56	Whole Gm	Total Am	Am-243	-	Other
Curium	46	Whole Gm	Total Cm	Cm-246	-	Other
Plutonium	50	Whole Gm	Total Pu	Pu-239+Pu-241	Pu-240	Special
Enriched Lithium	60	Whole Kg	Total Li	Li-6	Li-7	Other
Uranium-233	70	Whole Gm	Total U	U-233	U-232(ppm)	Special
Normal Uranium	81	Whole Kg	Total U	-	-	Source
Neptunium-237	82	Whole Gm	Total Np	-	-	Other
Plutonium-238	83	Gm to Tenth	Total Pu	Pu-238	Pu-238	Other
Deuterium	86	Kg to Tenth	D <sub>2</sub> O	D <sub>2</sub>	-	Other
Tritium	87	Gm to Hundreth	Total H-3	-	-	Other
Thorium	88	Whole Kg	Total Th	-	-	Source
Uranium in Cascades	89	Whole Gm	Total U	U-235	U-236	Other

 NRC Reportable Material Types

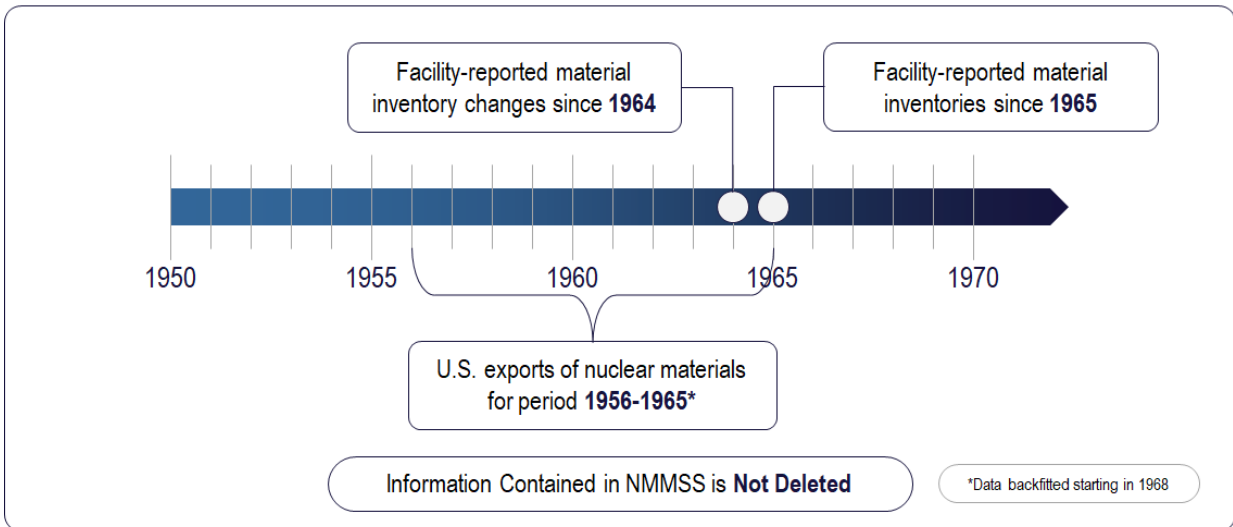
**Figure 2:** Types of Accountable Nuclear Material reported to NMMSS by DOE facilities and NRC licensees.

DOE sites use their own internal accounting systems (e.g., the Local Area Nuclear Material Accountability Software, LANMAS) to prepare reports to NMMSS. Although most large sites submit reports electronically in machine-readable format, analysts frequently need to engage with the sites to resolve errors and correct discrepancies. Information reported to NMMSS is subject to edit checks and other quality control routines, both automated in the system and manually applied by NMMSS analysts. Site data are periodically reconciled by NMMSS to match book inventory to physical inventory.

**2.2 Uses of NMMSS Information on DOE Accountable Material**

NMMSS is the successor to the material accounting practices established in the 1940s under the Manhattan Project and the Atomic Energy Commission (Figure 3). Since the beginning of data collection, the information has served multiple purposes. The operational, safeguards, security, and financial aspects of material accounting have long been intertwined. Operational needs were paramount early. Special nuclear material was difficult and expensive to produce and separate for military use, and all material was owned, controlled, and used by the government. As this policy

began to change with the *Atoms for Peace* Program, the interplay of the different purposes became more clear. Material accounting practices evolved and became more effective as measurement techniques improved while the government inventory of nuclear material grew. Some accounting and control responsibilities moved out of government hands as private ownership of SNM was allowed under law. Export and import of government-owned nuclear material added additional complexity to the system.



**Figure 3:** Historic timeline of U.S. data collection on government-owned accountable nuclear material accessioned in NMMSS.

Currently, material accounting data on government-owned material in NMMSS serves four interconnected purposes:

- U.S. domestic safeguards for material control and protection
- Allocation of material in support of policy decisions
- Financial tracking of government assets
- Reporting to the IAEA and to U.S. trading partners as specified in international agreements.

As previously noted, inventory data is used in defining and implementing the graded approach for material control and protection. Safeguards implementation is thus an inherent use of accounting data. Established facilities have well established accounting and control programs, but these may need revision as policy decisions impact site inventories and material uses. In many cases, such policy changes both depend on accountancy data and drive changes in reporting by facilities.

Some clear examples of the use of these data and the impacts on accountancy are documented in the report *Plutonium: The First Fifty Years*, published in 1996 [4]. This landmark study summarized recently declassified accountancy data from NMMSS, along with other historical reports and memoranda. The report documents how changing policy priorities affected production priorities and material allocation over the course of the Cold War. It also provides a snapshot of government priorities for this material at the time of publication.

This report has not yet been formally updated, despite changes in inventories, allocations, and policy since 1996 (for example, the report predates the formation of the NNSA, the organization now

responsible for material allocation). NNSA has expressed some interest in supplementing this report to cover material accountancy history in the years since and provide an unclassified view of current program priorities.

Other allocation decisions for government-owned nuclear material are similarly informed by NMMSS accountancy data, as documented in DOE reports to Congress (e.g., for enriched uranium [5]), although in some cases the source data remained classified (e.g., [6]). The increased interest in advanced reactor designs in recent years has drawn attention to potential commercial uses of government-owned accountable materials in development and initial deployment of such designs. This includes potential production of high-assay low-enriched uranium (HALEU) fuel from government-owned high-enriched uranium (HEU), as well as interest in other SNM previously designated for disposition (e.g., uranium -233 [7]). The latter case shows the linkage between allocation and financial uses for the accountancy data. The financial value to the government of a material inventory is tied to its potential use. When a new potential use emerges for a material, it can become an asset on the ledger. In a similar fashion, policy decisions can diminish (or entirely remove) the value of a former asset. DOE has well-developed processes for lifecycle management of government-owned accountable nuclear materials used and held at its sites, including the determination that final disposition is the best option [8].

DOE/NNSA uses a system of Project Numbers to track accountable government-owned material against specific tasks both at its facilities and at NRC licensees performing work for the government. Inventory and transaction reporting for government-owned material. The Project Number approach is given in the DOE Standard for material accounting [9] and the reporting guidance is detailed in the NMMSS Users Guide [2]. The Project Numbers are carried into NMMSS for the different materials, and the list of active projects is periodically updated to align with current mission requirements. Project Numbers are a key component of the financial asset tracking needs.

The other major use of the accounting data on government-owned material in NMMSS is fulfill U.S. commitments on reporting to the IAEA and to nuclear trading partners. The U.S. reports under three safeguards agreements with the IAEA (Figure 4), two of which involve government-owned material. Under INFCIRC/207, the U.S. reports imports and exports of source and special nuclear material each month. Under its Voluntary Offer safeguards agreement (INFCIR/288), the U.S. provides the IAEA a list of government and commercial facilities eligible for IAEA safeguards. At present, four commercial sites are selected by the IAEA for limited safeguards, and one government facility has full safeguards in place. NMMSS is responsible for producing the periodic reports for these activities and facilities for submittal to the IAEA.

INFCIRC	Description	Report Types	Frequency
207	Imports and exports	ICR	Monthly
288	Domestic and international movements of materials to and from the U.S. facilities selected by the IAEA	ICR PIL MBR	Monthly Annually Annually
366	Modified small-quantity protocol (SQP) reporting movements of nuclear material to and from the U.S. territories to the Caribbean	ICR PIL	Annually Annually

**Figure. 2:** U.S. reporting under its IAEA Safeguards Agreements. Government-owned accountable material is reported to the IAEA under INFCIRC/207 and INFCIRC/288. No government-owned nuclear material is currently in the U.S. Caribbean Territories covered by INFCIRC/366. **ICR** = Inventory Change Report. **MBR** = Material Balance Report. **PIL** = Physical Inventory Listing.

The government facility selected by the IAEA stores material that has been declared excess to defense purposes and is designated for disposition. The U.S has volunteered a portion of that material for full IAEA safeguards, including reporting, containment, surveillance, and inspection). The U.S is working with the IAEA to maintain safeguards on the material as it moves through the disposition process. The transactions and inventories from this disposition process will be submitted to NMMSS for the IAEA reporting. NMMSS is working with the processing and disposition sites to ensure that the U.S. meets its IAEA commitments.

NMMSS also collects and maintains information on nuclear material imported to and exported from the U.S. under Nuclear Cooperation Agreements (NCAs). In accord with Section 123 of the Atomic Energy Act of 1954, as amended, the U.S. enters into NCAs to ensure that nuclear materials are used for peaceful purposes. The U.S. currently has 24 NCAs with its trading partners, including Euratom and the IAEA. The NCAs and their Administrative Arrangements call for regular exchanges of information on nuclear materials that carry peaceful use obligations. Most foreign-obligated nuclear material in the U.S. is in the private sector (the largest amount being as commercial reactor fuel, spent fuel, or material in the reactor fuel cycle), but some government-owned material carries obligations. The government-owned material with obligations includes fuel from foreign research reactors that has been returned or recovered to the U.S. and is now at government facilities. This material is included in the NMMSS-generated reports of obligated material.

### 2.3 Lessons Learned and Ongoing Challenges

The complex nature of the accounting for government-owned nuclear material and the multiple uses for the accounting information require a NMMSS to be both robust and reliable while at the same time having the flexibility to respond to queries from its users. Each year, NMMSS processes more than a half-million individual records and generates nearly ten thousand separate reports, more

than half of which are for DOE sites with government-owned material. Several key attributes reflect the design and operational lessons refined over the years:

- **Communications and staff expertise** – open channels of communication between the reporting facilities and the NMMSS analysts is fundamental to effective and efficient material accounting. Good communication in turn requires knowledgeable and well-trained analysts at NMMSS and accounting staff at the sites. NMMSS promotes communication and training through the annual NMMSS Users Training conference, as well as detailed in-person and online training classes for site reporters.
- **Established reporting formats and electronic data submittal** – although each site is to some extent unique in its reporting needs, the use of standard formats and codes in the reported information greatly facilitates data capture. The nominal format for most transaction and inventory reporting follows a set of “forms” which derive from earlier paper form submittals. While most facilities submit machine-readable data, some sites with government-owned material still submit data in electronic versions of the paper forms, which can require the analysts to manually re-enter the data into the NMMSS database. NMMSS is implementing additional means to submit through virtual “fillable forms” that can capture the entries electronically without the need for manual retyping.
- **Rigorous Quality Control** – an accounting system is only as good as the information it contains. The NMMSS analysts run a set of automated edit checks on all submitted data to detect and correct first order errors (e.g., in formatting or improper coding). The analysts perform further manual quality control before accepting the submittal into the database. Discrepancies that arise at this step are resolved through direct communication with the submitting site. Analysts periodically reconcile each facility’s records to its physical inventory to provide further quality control.

While building on its success in material accounting, NMMSS faces several challenges in the near and long term, from internal and external forcings. NMMSS needs maintain its current functionality while building for future changes. These challenges will impact its mission for both the government and commercial nuclear sectors.

- **Preparing for and adapting to a changing nuclear landscape** – commercial deployment of advanced reactors in support of decarbonizing energy production has wide political support. In the U.S., industry is looking to the Federal government to seed an advanced reactor fuel cycle with appropriate material to support different technologies with different fuel requirements. One common interest is for government HALEU for several different fuel designs. Recent increased commercial interest in nuclear material for space and civilian navel deployment may also require NMMSS to adapt to handle new types of facilities with government-owned material and increased transactions between government and private entities. In parallel, NNSA is expanding and reconfiguring its facilities in response to Congressional direction on national security efforts. These changes may require NMMSS to increase its capacity and flexibility.
- **Capturing knowledge and connecting practices to policy** – at the same time that the nuclear landscape is changing, the U.S. nuclear workforce is experiencing significant turnover as the longstanding generation of material accountants and managers retires. This is now a critical juncture for documenting the corporate knowledge of best practices and the specific

experience at each site while staff are still available. A key part of this knowledge to capture is the connection between government policies, which changed over time, and the reporting and data handling practices designed to implement those policies. Individual knowledge can fill in historical gaps in the record.

- **Maintaining and developing skilled staff** – the corollary to knowledge management from experienced staff is the recruitment, development, and retention of the next cohort. Workforce planning and development has a high level of interest across the entire community. The NMMSS Users Training conference in May 2024 included a well-received panel discussion on workforce development, with plans for further presentations on progress planned for future meetings.
- **Incorporating modern information management technology** – NMMSS has ongoing efforts to maintain and improve the current NMMSS software while ensuring current functionality. The underlying code reflects the incremental evolution over many years and the supporting platform has not been rebuilt in some time. NMMSS has begun exploring options to modernize the system from the ground up, as resources become available, with no disruption in its mission services. As part of the preparation, the in-house development staff are supplementing the code documentation and identifying potential efficiency gains. The modernization effort also provides an opportunity to incorporate additional staff tools for quality assurance that can utilize advances in machine learning and artificial intelligence to better identify data anomalies for analyst attention.

NMMSS staff are actively addressing these challenges as the system continues to perform at a high level in support of NNSA decision making.

### 3. Conclusions

NMMSS provides data analytics, products, and services to inform policy decisions and responses to domestic and global developments. Accountancy of government-owned material is an important part of the NMMSS mission, and its importance will only increase in the future with potential expansion of both the government and commercial nuclear sectors.

### ACKNOWLEDGEMENTS

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### REFERENCES

- [1] *Nuclear Material Control and Accountancy*. U.S. Department of Energy Order 474.2A. Revision 2-7-2023.
- [2] *Nuclear Materials Management and Safeguards System (NMMSS) Users Guide*. Rev. 2.1. 2017.
- [3] *Instructions for Completing Nuclear Material Transaction Reports (DOE/NRC Forms 741 and 740M)*, NUREG/BR-0006, U.S. NRC, Washington, DC, 2020. *Instructions for the Preparation and Distribution of Material Status Reports (DOE/NRC Forms 742 and 742C)*, NUREG/BR-0007, U.S. NRC, Washington, DC, 2020.

- [4] *Plutonium: The First 50 Years, United States Plutonium Production, Acquisition, and Utilization from 1944 through 1994*. DOE/DP-0137. U.S. Department of Energy. 1996.
- [5] *Excess Uranium Inventory Management Plan*. U.S. Department of Energy Report to Congress, 2013.
- [6] *Tritium and Enriched Uranium Management Plan Through 2060*. U.S. Department of Energy Report to Congress, 2015.
- [7] *Alternate Fuels: Thorium and Uranium-233*. U.S. Department of Energy Report to Congress, 2023.
- [8] L. Gunn and R. Magleby. *Programmatic Value Determination Process for Accountable Nuclear Materials*. INMM/ESARDA Joint Meeting Proceedings. 2023.
- [9] *Nuclear Materials Control and Accountability*. U.S. Department of Energy Standard DOE-STD-1194-2019. 2019.