Trilateral Initiative Inventory Monitoring Systems for Facilities Storing Classified Forms of Fissile Material

Dennis Mangan ,John Matter and Ivan Waddoups
Sandia National Laboratories
United States
Gennady Pshakin
Institute of Physics and Power Engineering
Russian Federation
Mark Abhold
Los Alamos National Laboratory
United States
Igor Kuleshov,
International Atomic Energy Agency

Abstract

In the framework of the Trilateral Initiative, for the verification of weapon-origin and other fissile material specified by States as released from its defense programs, the Russian Federation, the United States, and the International Atomic Energy Agency have been engaged in discussions concerning the structure of reliable monitoring systems for storage facilities having large inventories of fissile material. The intent of these monitoring systems is to provide the capability for the IAEA to maintain continuity of knowledge in a sufficiently reliable manner that should there be equipment failure, loss of continuity of knowledge would be restricted to a small population of the inventory, and thus re-inventory of the stored items would be minimized.

These facility-specific Inventory Monitoring Systems (IMS) provide the principal means for the IAEA to assure that the containers of fissile material remain accounted for under the Verification Agreements which are to be concluded between the IAEA and each of the two States. .

The classified characteristics of the material under control impose an additional burden on the IMS developer. There should be taken into account such requirements as information barrier implementation and national security considerations. From an operational perspective the IMS are to be technically simple, reliable, economically efficient and impose minimal burden on the operator.

This paper will provide a summary of the approaches to the IMS as it currently exists.

Introduction

In the course of broad and productive discussions of inventory monitoring technologies the experts focused on technologies that would have near term application to facilities anticipated to be offered for verification pursuant to the Trilateral Initiative.

Due to the specific character of materials which are planned to be under the IAEA verification, we should take into account not only well known measures and methods of the International Atomic Energy Agency safeguards practice but primarily the need to protect secret information about weapon origin fissile materials.

To marry two opposite groups of demands one should find minimally intrusive and highly reliable methods and technologies of material measurements as well as monitoring technologies to support and simplify the IAEA verification process.

Technology Considerations

An IMS for the Trilateral Initiative is intended for the monitoring of a large number of containers with nuclear materials in a large storage facility. The major technical considerations are:

- Very large facilities to monitor and related cost of monitoring
- Large number of items at the facility
- Routine movements into storage
- No routine movement after placement in storage for several years
- Annual safety inspections that may require movement of specific items
- State security concerns that limit available technologies and equipment and impose special requirements for authentication
- Verification activity conducted under a bilateral agreement with some information provided from the state system for material accountancy and control
- Long time needed to bring a selected item for verification to an agreed place

General Principles

An IMS is intended to ensure that continuity of knowledge (CoK) is maintained over inventory items that have been accepted for monitoring by the IAEA. Some of the important general principles are:

- The systems shall be constructed with information barriers if required by the Host State
- The systems shall assure that credible and independent conclusions can be drawn by the IAEA
- For facilities that store fissile material with classified characteristics, all IMS data must be reviewed at the facility and only information as agreed between the IAEA and the State may be removed
- Because the storage facilities under consideration are expected to hold a large number of containers with fissile materials, the IMS must avoid the need for re-verifying the full inventory or even any substantial part thereof
- The IMS must be designed and operated in a manner that minimizes interference into the routine operations of the facility
- The IMS is to provide CoK in the periods between the inspections.

Functions

The primary functions of the IMS are to:

- Establish unique identification of items (number, bar code)
- Track item locations
  - during storage
  - during movements
- Monitor item integrity.

Implementing the IMS

The framework for implementing an IMS is based on LASSO (Layered and Segmented System Organization) as shown in Figure 1.

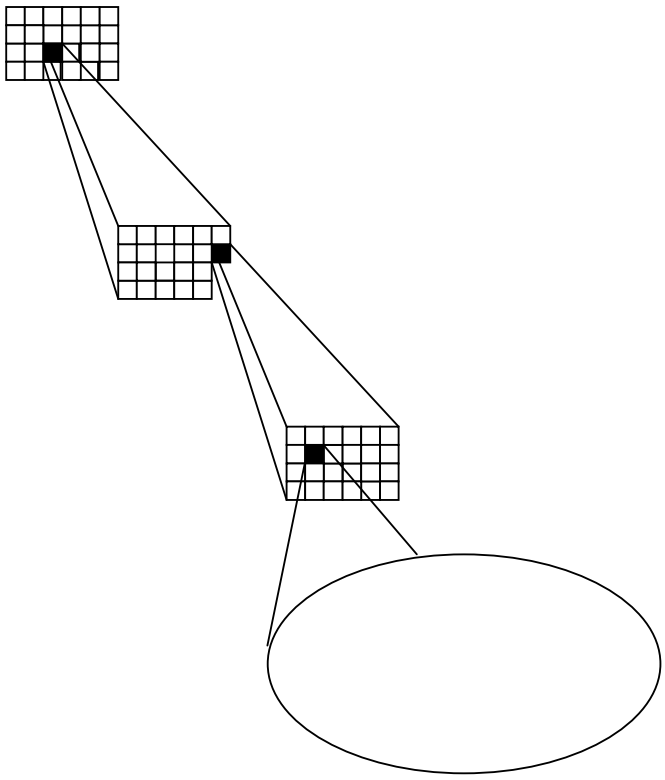

Figure 1. Layers and segments in the LASSO concept.

- The IMS shall have a series of nested *layers*, each of which covers the entire inventory. Each layer consists of one or more overlapping or contiguous *segments*. As a rule, moving from the outer layer to the inner layers, each segment applies to a smaller and smaller set of items. This provides further localization of a possible loss of CoK to smaller subsets of the

inventory with each subsequent layer of sensors. The innermost layer may consist of sensors that monitor individual containers. Only if this innermost layer and the corresponding elements of all preceding outer layers have failed will CoK be completely lost

- The IMS should be designed such that the number of inventory items that need to be re-verified at each inspection due to failures is not more than the IAEA random sample size for re-verification
- Continuity of knowledge (CoK) can be maintained in one layer if it is lost in another layer, or in one or more segments of another layer. The overall IMS capabilities and the layers and segments for which CoK is lost determine the requirements for reverification
- Each layer adds to the effectiveness of the IMS by:
  - increasing the overall probability that any attempt to remove containers will be detected;
  - increasing the reliability of the IMS in that if one layer fails another independent layer is unlikely to have a common mode failure
  - if one of the layers fails, the other layers will still provide assurance that will allow the full IMS to be returned to service without the need to completely reverify the stored inventory
- To the extent possible, no single failure shall cause loss of CoK that requires re-verification of a substantial portion of the inventory. This implies that any loss of CoK should be localized to a small portion of the inventory and hence a small portion of the IMS.
- The number of layers and segments will depend on several factors, in part related to the characteristics of the material, the facility specifics and the IMS technologies used.

Loading / Unloading

During loading and unloading of the storage facility, the IMS must operate under slightly different conditions:

- During the facility loading phase, the IMS will be built up starting with the innermost layer of individual item segments and continuing through each layer filling each segment at a time and successively each layer to the outermost layer. Not until the facility is fully loaded will all LASSO segments and layers be fully implemented, yet the IMS will be effective for monitoring CoK of all parts of inventory as it grows.
- As material disposition activities commence with the associated unloading of long-term storage, the items will be removed in a succession that essentially reverses the loading sequence. The IMS will be removed in the innermost layer in a series that completely vacates a segment in that layer and then progressively vacates segments in successively outer layers until the facility is completely unloaded.

General IMS Requirements

The IMS with LASSO must satisfy several operational requirements:

- The IMS shall function without servicing for a period not less than the interval between planned inspections.

- In case of failure of the data collection system or of the connection between the data collection system and the data generators, data shall be stored in the buffer memory of the data generators. Buffer memory shall have the capability to store data under normal operations at least for the longest expected period between inspection visits by the IAEA.
- Any IMS power failure and any restoration of power shall be noted in a state-of-health information file.
- Data filtering and/or data compression shall not cause the loss of a relevant event.
- Daily time synchronization and a common time base shall be provided for all subsystem clocks to within one-second maximum drift per day. The resolution of the system time stamp clock shall be higher than the shortest data collection period. After a loss of power or other interruptions, the system shall perform an immediate synchronization of all subsystem clocks upon restoration to normal operation

Hardware Requirements

- IMS will include multiple sensors and redundant data collection units
- Seals and tampering indication must be implemented to protect IMS equipment
- The IMS must be designed to prevent the loss of any data in case of mains power or communications failures.

Software Requirements

- Software shall be designed so that the system automatically restarts after interruptions of normal operations
- The software shall provide the capability for visual displays
- The software shall produce a performance summary file
- After the IAEA has completed servicing, the software shall provide a visual indication of correct setup
- Software reloading by the IAEA must be possible following repair or maintenance
- The system software shall be protected from tampering
- When the IMS includes intelligent data review, the verification data from contiguous IMS LASSO segments must be analyzed in such a manner that the operations carry over from one segment to the next allowing transactions to be followed automatically.

Data Generation and Collection Requirements

- Data from individual IMS elements must be stored independently and be capable of being reviewed and analyzed independently.
- Data shall be saved in buffered memory.
- Data must be date and time stamped at the time of generation.
- Authentication information shall be embedded into the data record at the time of, or before, transmission from the data generator.

- State-of-health data of the IMS system elements shall be made available to the facility operator. State-of-health data shall be stored in non-volatile memory at selected intervals for the period between inspection visits.
- Data retrieved by the data collection computer shall have unique identifying features that assure that there are no missing records

Authentication

- All relevant verification information shall be authenticated by an IAEA approved means
- Any triggering signals generated by a sensor shall be authenticated
- Authentication of IMS and system components shall pass an IAEA approved independent vulnerability assessment
- When authentication cannot be implemented directly on a sensor, a physical system of tamper indication must be used between the sensor and the point at which data authentication is applied.

Classified Information Protection

- Information barriers shall be implemented as necessary to prevent the release of classified information
- Any failure shall not lead to classified information disclosure
- The possibility of obtaining classified information by means of unauthorized access shall be excluded
- Any system elements that contain classified information shall be protected against unauthorized access

Possible Areas of Future Activity

The Trilateral Initiative technical experts working group for inventory monitoring systems has identified several possible areas of future activity.

- Develop the next level of detail associated with the IMS for a specific facility
  - design and implementation guidelines
  - qualification standards for equipment and procedures
  - requirements for the joint use of equipment
- Develop the relevant parts of the Technical Criteria for IAEA verification
- Further develop the LASSO approach to IMS
- Produce a preliminary design of inventory monitoring systems for the proposed RF and US storage facilities
- Conduct a feasibility study of computer modeling of the locations and activities carried out within the controlled parts of the proposed facilities
- Conduct a feasibility study of neutron monitoring as an integral part of IMS.

Reference

1. General Technical Requirements, Inventory Monitoring Systems (IMS) for Facilities Storing Fissile Material with and without Classified Characteristics, Version 2.0, 4 April 2001, (Provisionally Agreed).