24. Introduction to Nuclear Material Accounting and Control (NMAC) for Nuclear Security

April 29 – May 18, 2018
Albuquerque, NM USA

Learning Objectives

After completing this module, you should be able to:

• Describe the role of Nuclear Material Accounting and Control (NMAC) in comprehensive nuclear security at a facility
• Identify differences between the use of NMAC for IAEA safeguards and for facility nuclear security
• List benefits of NMAC accounting function
• List benefits of NMAC control function
• Describe process for resolution of irregularities
IAEA Nuclear Security Series 13 (NSS-13)

3.26 The operator should ensure control of, and be able to account for, all nuclear material at a nuclear facility at all times. The operator should report any confirmed accounting discrepancy in a timely manner as stipulated by the competent authority.

What Does NMAC System Do?

- Provides information to the facility operator:
  - Type, quantities, and location of the nuclear material
  - Definition of facility accounting boundaries, known as material balance areas (MBA)
- Tracks nuclear material through storage, handling, use, and disposition
- Provides administrative and technical measures to control nuclear material during all activities
How NMAC Contributes to Nuclear Security

- When properly implemented, NMAC measures can detect unauthorized removal of nuclear material by an insider
  - Possibility of being detected serves as a deterrent to the insider to not attempt the malicious act
  - NMAC system provides the primary way of detecting protracted theft (multiple thefts of small quantities)

- If nuclear material is stolen
  - NMAC can provide critical information about what has been stolen—material type and quantity—to ensure that any recovery of the material is complete
  - NMAC system can provide legal evidence about the inventory of the facility to be used in court
NMAC and Insider

- Example of how NMAC aids physical protection system
  - A nuclear facility includes the best physical protection system in the world—best guns, toughest fences, and smartest guards
  - At the end of a shift, the workforce leaves the facility, passes through the access control point, gets in vehicles, and drives out of the parking lot
- Did a nuclear material theft occur?
  - The physical protection system may not be able to answer that
  - NMAC measures can deter theft by an insider and has the information necessary to resolve questions of theft

NMAC and Outsider

- Example:
  - An external assault team has just attacked a nuclear facility
  - Can you tell if a theft of nuclear material occurred?
    - Probably—through visual observance, radiation portal monitors, and other physical protection or safety alarms
  - Can the physical protection system tell what was stolen?
    - No—only NMAC system can do that
Overlap between NMAC/Physical Protection

- Because of NMAC and Physical Protection overlaps, careful coordination and well defined communications are required.

- Examples of important areas for coordination:
  - Control of access to nuclear material
    - Coordination between NMAC, Physical Protection, and Operations is needed to determine who has access, when access to nuclear material is necessary, and how it is authorized.
  - Prohibited item detection (X-ray, metal detectors)
    - Materials that can be used to shield nuclear material from radiation detectors must be designated as prohibited items as well as typical materials considered.
  - Surveillance
    - Some measures or equipment (e.g., two-person rule, cameras) may be used by either or both NMAC and Physical Protection.
    - Facility procedures should designate which organization(s) are to receive the resulting information on a need-to-know basis.
IAEA Safeguards and Facility Nuclear Security

- **Safeguards**
  - Detect a State’s clandestine nuclear weapons program
  - Verify correctness of a State’s declaration to provide meaningful assurance of non-diversion of declared nuclear material

- **Nuclear Security**
  - Prevent and/or detect attempts to steal nuclear material by a terrorist or criminal Insider
  - Protect against non-State actors (criminal, terrorist, etc.)

Why Is NMAC Accounting So Important?

- A facility licensee must know what materials they have in order to:
  - Design effective physical protection (security) systems
  - Track, ship, and receive nuclear materials
  - Assist in identification and recovery of stolen material
    - Is the material in bulk or an item?
    - What form is it?
    - Is it easily transportable?
    - What is its mass and isotopic composition?
    - How was it measured and what is the error?
NMAC Uses Material Balance Areas (MBA)

- An MBA is a designated area in a nuclear facility that facilitates accounting of material:
  - Quantity of nuclear material during each movement into or out of an MBA can be determined.
  - A physical inventory of nuclear material in each MBA is conducted periodically to establish the quantity of nuclear material in MBA and material balance.
- For security use and to enhance control, an MBA for security is typically smaller than for Safeguards.

Material Balance Equations – General Theory

- Material inventories and flows must “conserve mass”:

  \[
  MB = \text{Begin Inventory} - \text{End Inventory} + \text{Input Transfers} - \text{Output Transfers}
  \]

- Material Balance Equation:
  - MB is sometimes referred to as:
    - Inventory Difference (ID)
    - Material Unaccounted For (MUF)
What Does MUF Tell Us?

• Material Unaccounted For (MUF) is the difference between the amount of material that (a) *should be* in the MBA, based on accounting records and (b) *is actually there*, as established by Physical Inventory Taking
  - MUF should be zero, but it could be positive or negative
  - A non-zero MUF must be investigated to determine why it is not zero
  - A non-zero MUF could be the first indication of unauthorized removal by an insider
• When an unscheduled Physical Inventory Taking is conducted because of an alarm condition, the results of the MUF calculation provide information on whether an unauthorized removal occurred

Examples of Measurement Techniques

• Physical techniques
  - Weight
  - Volume
  - Heat
  - Elemental light emission
• Nuclear techniques
  - Gamma rays
  - Alpha particles
  - Neutrons
NMAC Physical Inventory Taking (PIT)

- Nuclear facilities conduct periodic physical inventories
  - All nuclear material should
    - Be measured at the time of physical inventory, or
    - Have a prior measurement whose integrity is assured
  - Physical inventory results are compared to accounting book inventory
    - Confirms the presence of nuclear material
    - Confirms accuracy of the book inventory
    - Provides evidence that facility accounting system is effective

Movements of Nuclear Material

- Nuclear material is particularly vulnerable during movements, which can include
  - Shipments and receipts between facilities
  - Transfers within a facility between MBAs
  - Relocations within an MBA
- NMAC assists by requiring that a strict set of procedures be followed during material movement, including use of
  - Two person rule
  - Sign off by MBA custodians
  - Verification measurements, etc.
Why Is Nuclear Material Control So Important?

- Maintain continuity of knowledge about nuclear material properties, including their location
- Control who has access to the materials
- Help detect any unauthorized handling or movements
- Identify irregularities that may have occurred

Examples of Nuclear Material Control

- Several of these examples will be discussed in following slides
- Red indicates overlap between NMAC and Physical Protection

<table>
<thead>
<tr>
<th>Example</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material access control</td>
<td>Administrative checks</td>
</tr>
<tr>
<td>Two-person rule</td>
<td>Authorization of activities</td>
</tr>
<tr>
<td>Material containment</td>
<td>Compartmentalization</td>
</tr>
<tr>
<td>Material surveillance</td>
<td>Tie downs</td>
</tr>
<tr>
<td>Tamper indicating devices</td>
<td>Dual locks and key combination control</td>
</tr>
<tr>
<td>Item monitoring</td>
<td>Radiation portal monitors</td>
</tr>
<tr>
<td>Monitoring material during processing</td>
<td>Handheld monitoring (for radiation / metal)</td>
</tr>
</tbody>
</table>
Example: Controlling Access to Nuclear Material

• Physical protection system normally controls access to areas such as
  ▪ Facility
  ▪ Protected areas
  ▪ Buildings

• Employees are authorized to access these areas
  ▪ An employee can be considered as a potential insider

• NMAC and physical protection system together are intended to control access to nuclear material by insiders

Example: Material Containment

• Purpose
  ▪ Deter and detect any actions that could lead to unauthorized removal or misuse of nuclear material

• Material containment can be provided by
  ▪ Structural features of a facility, containers, or equipment used to establish the physical integrity of an area or items
  ▪ Examples include vaults, storage containers, storage pools

• Material containment is most effective when used with material surveillance
Example: Material Surveillance

- Material surveillance is intended to detect unauthorized access to or movement of nuclear material
- Methods of surveillance include:
  - Administrative measures
  - Technological measures
- Note
  - This training course discusses material surveillance measures implemented by the Operator as part of the facility’s Nuclear Security program
  - It does not address material surveillance measures implemented for the purposes of IAEA Safeguards

Example: Tamper Indicating Device (TID)

- TIDs
  - Are applied to objects for the purpose of detecting unauthorized access
  - Have a unique identifier
  - Do *not* protect the physical integrity of the object
  - Are designed to indicate that access has occurred
Example: Item Monitoring

- Nuclear material item
  - Discrete container of nuclear material
  - Discrete piece of nuclear material
- Information verified during monitoring includes
  - Integrity
  - Location
  - Identification
- Items of nuclear material should be monitored between scheduled physical inventories

Example: Monitoring during Processing

- Control of nuclear material should be maintained during processing
- Monitoring during processing
  - Generally a statistic evaluation of the input and output of the process to detect any unauthorized removal
  - Can be implemented around a single process unit or processing line
When NMAC Uncovers an Irregularity ...

- **What is an irregularity?**
  - An unusual observable condition which might result from unauthorized removal of nuclear material, or which restricts the ability of the facility operator to draw the conclusion that unauthorized removal has not occurred (NSS 25-G)

- **Essentially, an irregularity “triggers” an investigation**
  - For nuclear security, the investigation may determine whether the irregularity was caused by malicious insider activity

You can think of an NMAC irregularity like the small irregularities sometimes found in the construction industry, which often indicate a larger problem. For example, these micro cracks in concrete could lead to a bigger issue.

NMAC Irregularities Require an Investigation and Response

- Discovery of an irregularity by NMAC requires an investigation to determine appropriate response

- Examples that could lead to discovery of an irregularity are provided on the next slide
Detection of Irregularities Shortens Detection Time of an Insider Action

Example: Monitoring Irregularities

- A monitoring irregularity is a nuclear material item not in its recorded location
- Possible actions to respond
  - Conduct a search of the area adjacent to the location where the nuclear material item should be
    - Review the operations and accounting records for any movements of the item that were not accurately recorded
    - Notify security personnel if the item is not quickly located
  - Initiate an emergency PIT in MBA or location where the irregularity was discovered
    - Expand to the entire facility if the item is not located
Example: Shipping / Receiving Irregularities

- An irregularity is a difference between the shipper and receiver that exceeds the established criteria
- Possible actions
  - Isolate the shipment
    - Evaluate and recalibrate (if necessary) the measurement equipment
    - Check for other indications of unauthorized removal
    - Re-measure nuclear material items and re-check uncertainties from shipper and receiver (possibly by different organization to ensure no conflict of interest)
    - Interview receiving facility personnel; shipping facility and transport personnel
      - Confirm adherence to required procedures including the two-person rule if applicable

Investigation of Irregularities

- Formal, documented process per facility procedure
- Critical irregularity
  - For example, nuclear material missing from its assigned location
  - Requires immediate investigation and response
- Other irregularities
  - For example, item in incorrect location may not appear critical initially
  - Carefully investigate and treat as if irregularity indicates malicious insider activity and unauthorized removal of material
- Area and all nuclear material associated with possible irregularity should be isolated or protected until investigation is complete, if possible
Corrective Actions

- Address and mitigate all contributory factors and causes identified
  - Develop and implement a corrective action plan to address root cause
  - Actions taken to correct an irregularity depend on type and severity of irregularity
  - Facility procedures should identify level of management responsible for final correction of investigation and, where appropriate, required notification to the Competent Authority
  - Conduct follow-up evaluation to ensure actions taken to correct root cause are effective
  - Monitor irregularities to identify trends that could be indicative of insider attempts at unauthorized removal of nuclear material

Reporting

- Procedures for reporting irregularities should be developed before they are needed
  - All irregularities should be reported to facility management and to Competent Authority, if required
  - If nuclear material is determined to be missing, the facility contingency and/or emergency plan should be initiated
  - Discovery of an irregularity, investigation of the irregularity, and measures taken to correct the irregularity should be documented
Key Takeaways

- NMAC helps track and manage a facility’s nuclear material holdings, providing valuable information in an investigation
  - Types and quantities of nuclear material
  - Specific locations
- NMAC measures can serve as detection triggers
  - Initiate prompt investigation and resolution of irregularities involving nuclear material, reducing time in detecting insider activity
  - Act as deterrent to insider theft because of increased likelihood of detection