

Materials Control & Accountability (MC&A) Overview: PIT



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Nuclear Materials and MC&A Evolution

- **Manhattan Project creation during WWII**
 - Oak Ridge for graphite test reactor and uranium enrichment
 - Hanford for plutonium production
 - Los Alamos for weapons design, assembly, testing
- **Post-war Acts creating Atomic Energy Commission (AEC) with eventual evolution to DOE and NRC**
- **Financial accounting evolves to include safeguards during Cold War**
 - Increased number of sites, operations and inventories
 - Material losses and environmental releases
 - Potential insider and outsider threats
- **Post Cold War Issues**
 - Materials in countries with economical difficulties
 - At risk materials from disarmament agreements
 - Growing threats from terrorism
 - Downsizing and reconfiguration of facilities
 - ES&H compliance

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MC&A Regulations/Authorization/Oversight

- **National Agencies**
 - **In the US there are two authorizing organizations**
 - Department of Energy (DOE) for government materials and facilities (weapons production and research)
 - Nuclear Regulatory Commission (NRC) for private enterprises (enrichment, fuel fabrication, power reactors and research reactors, including universities)

Note: Military branches responsible for weapons/materials under their domain
 - **Other countries have one or more similar regulating agencies**
- **International Atomic Energy Agency (IAEA) for countries that have signed Agreements**

Purpose of an MC&A Program

- **Provide accurate accounting for Safeguards & Security and Financial Management Systems**
- **Timely detection of diversion of significant quantities of nuclear material and deterrence of such diversion by the risk of early detection**
- **Provide a crucial integrated component of the overall protection of nuclear materials**

Major MC&A Terms (DOE Glossary Defines ~500 Terms)

- Other common related names/acronyms
 - NMC&A, MAC, Safeguards & Security (S&S)
 - MPC&A (US-RF Program)
- Nuclear Material (NM)
- Special Nuclear Material (SNM)
- Material Balance Area (MBA)
- Book Inventory
- Physical Inventory
- Inventory Difference (ID) or Material Unaccounted For (MUF)
- Shipper/Receiver Difference (S/RD)
- Graded Safeguards

Accountable Nuclear Materials

| MATERIAL TYPE | SNM | SOURCE | OTHER NUCLEAR MATERIALS | REPORTABLE QUANTITY |
|-------------------|-----|--------|-------------------------|---------------------|
| Depleted Uranium | | X | | Kilogram |
| Enriched Uranium | X | | | Gram |
| Normal Uranium | | X | | Kilogram |
| Uranium-233 | X | | | Gram |
| Plutonium-242 | X | | | Gram |
| Plutonium-239-241 | X | | | Gram |
| Plutonium-238 | X | | | Tenth of a Gram |
| Americium-241 | | | X | Gram |
| Americium-243 | | | X | Gram |
| Berkelium | | | X | Microgram |
| Californium-252 | | | X | Microgram |
| Curium | | | X | Gram |
| Deuterium | | | X | Tenth of a Kilogram |
| Lithium-6 | | | X | Kilogram |
| Neptunium-237 | | | X | Gram |
| Thorium | | X | | Kilogram |
| Tritium | | | X | Hundredth of a Gram |

NM Exists in Many Shapes, Forms and Sizes



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NM Variations (continued)



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Reprocessing NM



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Title and Date



NM Safeguards Categories

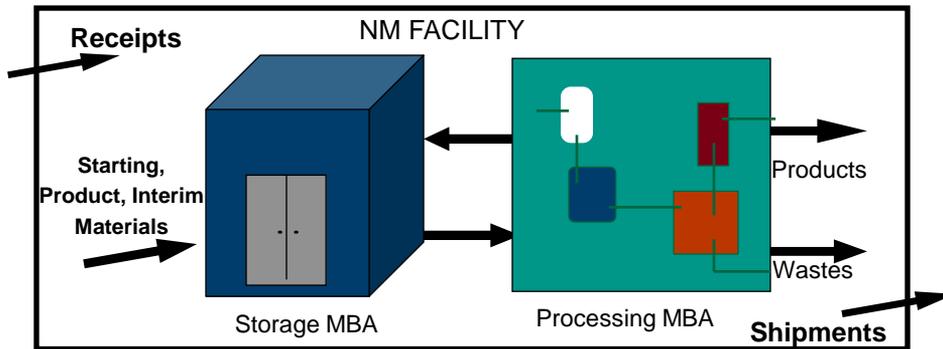
| | Attrac-tiveness Level | PU/U-233 Category (quantities in kgs) | | | | CONTAINED U-235 Category (quantities in kgs) | | | | OTHER NUCLEAR MATERIALS |
|--|-----------------------|---------------------------------------|----------------|------------------|-----------------------|--|---------------|----------------|-----------------------|-------------------------|
| | | I | II | III | IV | I | II | III | IV | IV |
| WEAPONS Assembled weapons and test devices | A | All Quantities | N/A | N/A | N/A | All Quantities | N/A | N/A | N/A | N/A |
| PURE PRODUCTS Pits, major components, buttons, ingots, recastable metal, directly convertible materials | B | ≥ 2 | $\geq 0.4 < 2$ | $\geq 0.2 < 0.4$ | < 0.2 | ≥ 5 | $\geq 1 < 5$ | $\geq 0.4 < 1$ | < 0.4 | N/A |
| HIGH-GRADE MATERIALS Carbides, oxides, solutions (≥ 25 g/l), nitrates, etc., fuel elements and assemblies, alloys and mixtures, UF ₄ or UF ₆ ($\geq 50\%$ U-235) | C | ≥ 6 | $\geq 2 < 6$ | $\geq 0.4 < 2$ | < 0.4 | ≥ 20 | $\geq 6 < 20$ | $\geq 2 < 6$ | < 2 | N/A |
| LOW-GRADE MATERIALS Solutions (1 to 25 g/l, process residues requiring extensive reprocessing, moderately irradiated material, Pu-238 (except waste), UF ₄ or UF ₆ ($\geq 20\% < 50\%$ U-235) | D | N/A | ≥ 16 | $\geq 3 < 16$ | < 3 | N/A | ≥ 50 | $\geq 8 < 50$ | < 8 | N/A |
| ALL OTHER MATERIALS Highly irradiated forms, solutions (≤ 1 g/l), uranium containing $< 20\%$ U-235 (any form any quantity) | E | N/A | N/A | N/A | Reportable Quantities | N/A | N/A | N/A | Reportable Quantities | Reportable Quantities |

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Basic MC&A Requirements and Design



- All NM identified and recorded with measured/defensible values
- All NM is located and controlled within defined material balance areas (MBAs); boundaries do not overlap
- NM transfers on measured values (include all movements –input, process, product, scrap, waste, environmental releases, etc.)
- Periodic complete physical inventory verification/reconciliation to book inventory
- Significant discrepancies and anomalies expeditiously identified and reported

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Typical Measurement Techniques

- Mass (mechanical/electronic scales), volume and density
- Destructive Analyses (DA)
 - Traditional gravimetry and titrimetry
 - Spectrophotometry - X-ray emission, inductively coupled plasma, colorimetry and fluorescence
 - Radiometry
 - Mass Spectrometry for isotopes and element
- Non-Destructive Analyses (NDA)
 - Neutron and gamma spectrometry for element and isotope
 - Calorimetry

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Sampling and Destructive Analyses (HEU Feed/HEU Oxide/NU Oxide/LEU Oxide)



Sampling

U Isotopes by Mass Spec



U by Davis-Gray Titration

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Examples of NDA Measurements



AWCC

Hold-up in ducts



Waste drum measurement



U/Pu Inspector
for U Enrichment



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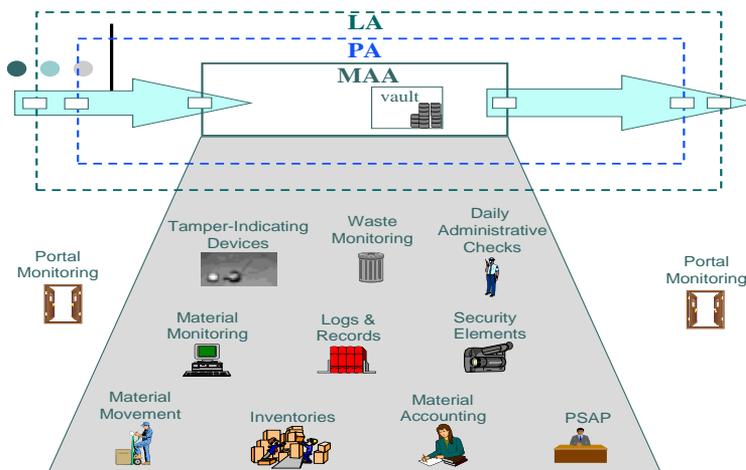
Primary Accounting Control Indicators

- **Missing Item**
- **Inventory Difference (ID) indicates loss (or gain) of material from the accounting system**
 - $ID = \text{Book Inventory} - \text{Physical Inventory}$, and in the case for regular inventory periods,
 - $ID = \text{Beginning Inventory} + \text{Receipts} - \text{Shipments} - \text{Ending Inventory}$: $ID = BI + R - S - EI$
- **The Shipper/Receiver Difference (S/RD) results from comparing the inventory records of the shipping Facility/MBA with the Receiving Facility/MBA**

Note: The last may appear simple, but applying the uncertainties for all the measurements involved (items, techniques, sampling) and determining limits on the ID is complex and challenging

MC&A Integration with Overall NM Protection

Human Reliability Program MC&A Protective Force
Physical Protection Computer Security Information Security



Potential Results from Ineffective MC&A

- Undiscovered Diversion/Theft
- Unexplained Loss
- Poor Criticality Safety
- Poor Environmental Stewardship
- False Responses
- Shutdown of Operations/Facility
- Loss of Credibility with Government, Citizens, and International Community
- Vulnerability for Adversarial Attack
- International Nuclear Threat

MC&A Summary

- Control & Accounting began in 1940s with NM creation, based on financial accounting
- Needs and capabilities changed as did the sensitivities and threats
- Accounting evolved from classical “bean counting” to near real-time computer systems, with tremendous data format and tracking capabilities
- Many new techniques have been and continue to be developed (DA and NDA measurements, Seals/TIDs, Surveillance, Process Monitoring, Controls and other support systems)
- MC&A systems today include:
 - Wide range of professionals - accountants, engineers, scientists, statisticians, administrators
 - Wide range of analytical measurement methods
 - Extensive specialized training
 - Dedicated, understanding, thick-skinned and politically savvy people to make sure materials don't fall into the wrong hands
- International threats and international cooperation abound

Optional MC&A Slides

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Material Safeguards for HEU Shipped from Vinca Institute to Dimitrovgrad



- Personnel access controls
- Multiple person operation
- Storage container and seal integrity checks
- Records verification
- U-235 confirmation by NDA (random sampling)
- Multiple tamper indicating devices (TIDs) on new containers

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Vinca HEU Air Transport



- Loading onto aircraft by transport crew under heavy security
- Final checks onboard by representatives of Serbia, Vinca, RF/STNM, and US/DOE



- All parties except aircraft crew and security repositioned to another controlled location
- Liftoff of Il'yushin 76 with HEU cargo - Aug. 22, 2002

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HEU Removal at Krylov Institute in St. Petersburg, Russia



Weighing, checking item identities & confirming TIDs on HEU fuel rods to be shipped



Enrichment check by NDA on LEU fuel rod after HEU removal

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MC&A Program Elements

- **MC&A Plan** – Documents program implementation details and requires approval by DOE office
- **Graded Safeguards** – DOE guidance prescribes consideration of material attractiveness and quantities for which to apply the appropriate levels of protection
- **Accounting System**
 - Consists of Facility/MBA Structure, Database Systems, Records & Reports
 - Must reflect all inventory, track changes, and allow reconciling physical inventory taking
- **Measurements** – Includes determining and qualifying methods and Measurement Control

MC&A Program Elements (Cont.)

- **Material Containment**
 - NM must be in authorized location within defined structures and areas
 - Access to, handling of and movements of material must be controlled
- **Material Surveillance** – Procedures and mechanisms to detect unauthorized activities or anomalous events with materials under normal or emergency conditions.
- **Physical Inventory** – Process Monitoring, Item Monitoring, Inventory Measurements, Inventory Preparation & Performance
- **Control Limits** – S/R Limits and Difference Evaluation, Inventory Limits & Difference Evaluation
- **Performance Evaluation** – Performance Testing, Assessments Program, Issues Management

Some Material Control Details

- **Material Containment**
Limited Area, Protected Area, Material Access Area,
Storage and Vaults, Processing Containment
- **Access Controls**
Personnel Access, Materials Access, Data Access,
Equipment Access
- **Material Surveillance**
Multiple Personnel, CCTV, Other Mechanisms
- **Detection Assessment**
TIDs, Portal Monitoring, Waste Monitoring, Daily
Administrative Checks, Other Mechanisms