IAEA Facility-Level Safeguards and Implementation

International Nuclear Safeguards Policy and Information Analysis Course

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Relevance of Facility Level-Safeguards and Implementation to this Discussion

- The focus of this course is International Nuclear Safeguards Policy and Information Analysis
- Course attendees may ultimately become Nuclear Safeguards Analysts or Safeguards Inspectors for the IAEA, or interact with the IAEA
- It is important for would-be Inspectors and Analysts to understand the foundation of International Nuclear Safeguards and how they are implemented **in declared nuclear facilities**
- This is also important because both Analysts and Inspectors participate in the annual IAEA State Evaluation Process
- **It should must also be recognized that Facility-Level safeguards are fundamental to implementing safeguards at the State-Level** - **(i.e.** Safeguards anomalies and discrepancies at nuclear facilities have implications for safeguards in the State as a whole.)

A High Level View of IAEA Safeguards

STATE LEVEL APPROACH

Correctness

(Declared Facilities and Activities)

- INFCIRC 153/66
- SSAC (domestic)
- Reporting
- Design Information
- Facility Attachment
- Inspections

Completeness

(Undeclared Facilities and Activities)

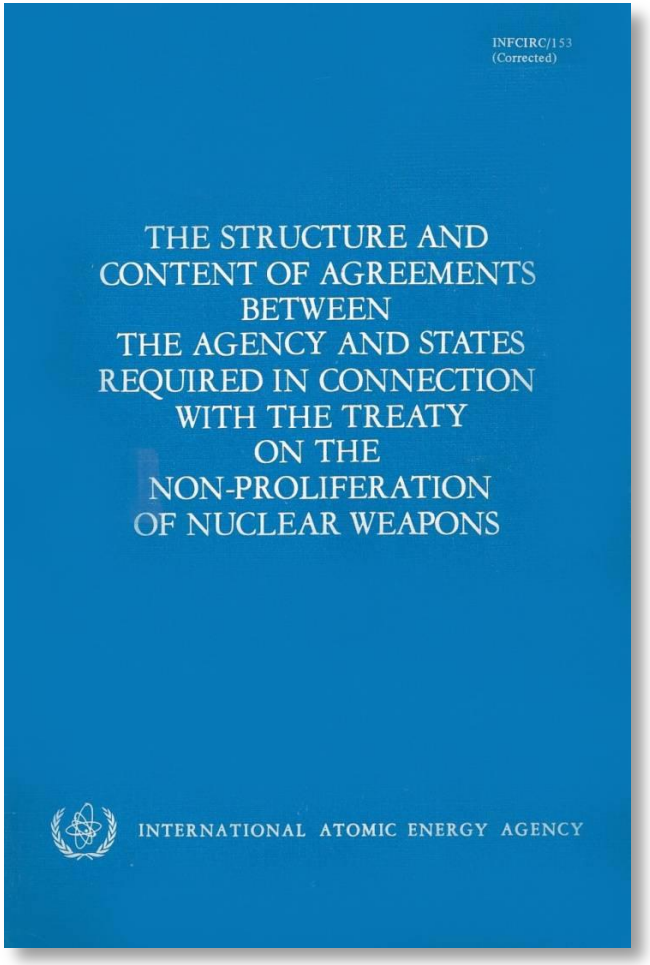
- INFCIRC 540
- Provision of Information
- Complementary Access
- Open Source Analysis
- Satellite Image Analysis
- National Technical Means

The Foundation of IAEA Safeguards – The Safeguards Agreement

- The legal basis and foundation for implementing International Nuclear Safeguards in the State is the Safeguards Agreement between the State and the IAEA
- The Safeguards Agreement is concluded pursuant to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT)
- The Safeguards Agreement allows for IAEA Nuclear Safeguards Inspectors to verify the nuclear material and the facilities that process, store, and handle nuclear material in the State
- The Safeguards Agreement establishes the basic provisions for how safeguards will be implemented in the State and at the facility level
- Most Safeguards Agreements are based on the IAEA Model Comprehensive Safeguards Agreement – INFCIRC/153 (corrected)
- Three states (India, Israel, and Pakistan) have older safeguards agreements based on INFCIRC/66 – but are the exception

Model Comprehensive Safeguards Agreement

IAEA INFCIRC/153 (corrected)



Model Comprehensive Safeguards Agreement – IAEA INFCIRC/153

Establishes:

- The Basic Safeguards Undertaking (pursuant to the NPT)
- The application of Safeguards on all Source and Special Fissionable Material (in all peaceful nuclear activities)
- That nuclear safeguards shall be based on Cooperation between the State and the IAEA
- That a State-System of Accounting for, and Control of all Nuclear Material (SSAC) shall be established – i.e. basis for Domestic Nuclear Safeguards
- That the State shall provide safeguards relevant Information to the IAEA in order to implement effective safeguards
- The starting point of safeguards and when safeguards can be terminated
- The objective of International Nuclear Safeguards
- Subsidiary Arrangements
- The use of Nuclear Material Accountancy as the fundamental safeguards measure
- The use of Containment and Surveillance (C/S), and other supportive measures
- etc.

INFCIRC/153 – The Structure & Content of Agreements Between the Agency & States in Connection with the NPT

- Guidance to the IAEA and State:

  PART I, paragraph 4, The Agreement should provide that safeguards shall be implemented in a manner designed:

  - (a) To avoid hampering the economic and technological development of the State … in the field of peaceful nuclear activities, including international exchange of nuclear materials;
  - (b) To avoid undue interference in the State's peaceful nuclear activities, and in particular in the operation of facilities; and
  - (c) To be consistent with prudent management practices required for the economic and safe conduct of nuclear activities.

Subsidiary Arrangements to the Safeguards Agreement (General Part and Facility Attachments):

- Subsidiary Arrangements to the Safeguards Agreement are concluded between the State and the IAEA
- These contain the administrative and technical procedures that specify how the provisions in the Safeguards Agreement shall be applied
- They consist of a General Part applicable to all nuclear activities in the State
- They also include Facility Attachments, which are specific to each nuclear facility or group of collocated facilities
- Facility Attachments specify the details regarding what facility data can be collected, how it can be collected, the types of facility instruments that can be used by IAEA inspectors, working hours for inspections, escort requirements, etc.
- Although some limitations may be imposed by the Facility Attachment, the IAEA must still be able to draw an Independent Safeguards Conclusion, regarding the nuclear material and facilities in the State

The Safeguards Agreement – (INFCIRC/153), para. 28

The Objective of Safeguards:

- "…the objective of safeguards is the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons, or of other nuclear explosive devices or for purposes unknown, and the deterrence of such diversion by the risk of early detection."

Key Words and Phrases:

- Timely Detection of Diversion
- Significant Quantities of Nuclear Material
- Deterrence by the Risk of Early Detection

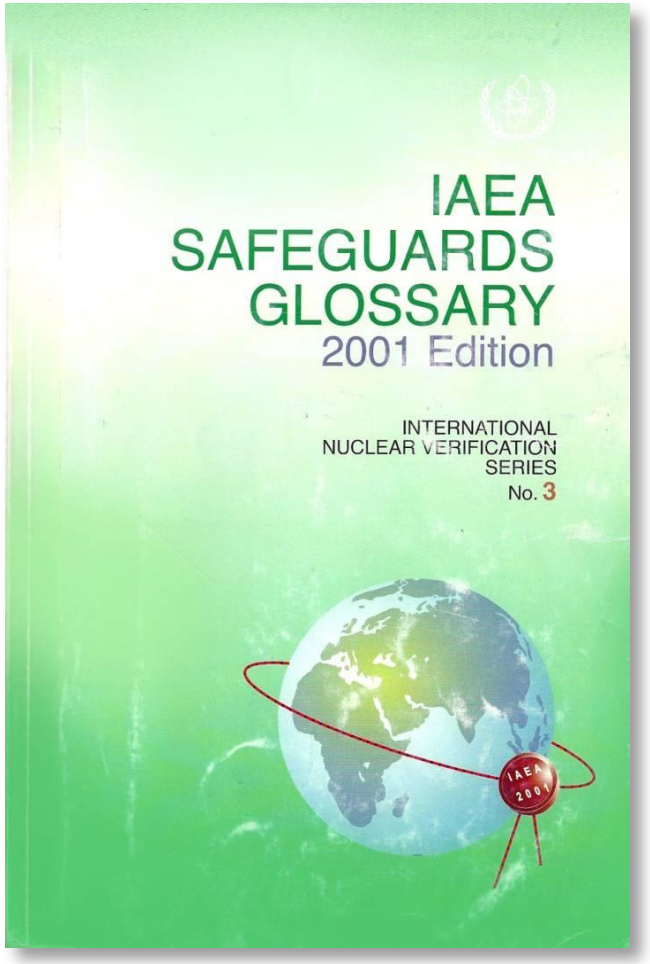
Other Key Terms and Concepts:

- Other relevant terms are defined on the following slides based on the IAEA Safeguards Glossary – (See the IAEA Glossary for more details)

Safeguards Glossary

Interpreting IAEA Safeguards

Terms, Definitions, and Concepts



The Objective of Safeguards (continued)

Significant Quantities of Nuclear Material:

(Source - IAEA SG Glossary 2001 Ed., Table-II Significant Quantities)*

Nuclear Material	Significant Quantity
• Plutonium	8 kg Pu
• U-233	8 kg U-233
• HEU (U-235 > 20%)	25 kg U-235
• LEU, Natural, and Depleted-U	75 kg U-235
• Thorium	20 tonnes Th

*See the Reference noted for more details

Did You Know?

According to the International Atomic Energy Agency (IAEA), 25 kg of HEU (about the size of a grapefruit) or 8 kg of plutonium (about the size of a soda can represent a “significant quantity” required to make a crude nuclear weapon.

The Objective of Safeguards (continued)

Timeliness of Detection:

(Source - IAEA SG Glossary 2001 Ed., Table-I and para. 3.20)*

Nuclear Material	IAEA Timeliness Goal
• Plutonium (unirradiated)	1 Month
• U-233 (unirradiated)	1 Month
• HEU (U-235 > 20%)(unirradiated)	1 Month
• Pu, U-233, and HEU (irradiated)	3 Months
• LEU, Natural, and Depleted-U	1 Year
• Thorium	1 Year

*The IAEA Timeliness Detection Goal is based on the time to convert the nuclear material to finished metallic components (suitable for fabricating nuclear weapons)

The Objective of Safeguards (continued)

Deterrence by the Risk of Early Detection:

- Facility Inspection Frequencies and Verification Requirements are established in the IAEA Safeguards Manual based on the type of nuclear material and the quantity handled
- The inspection frequencies are designed to allow the IAEA to meet the Timeliness Goals for Detecting a possible Diversion*

Facility Type	Interim Inventory Verification*
• Research Reactor	Quarterly or Annually
• LWR	Quarterly
• Uranium Enrichment Plant	Monthly
• Spent Fuel Reprocessing	Monthly
• PuO_2/MOX Fabrication	Monthly

* These are typical examples, although the frequency may vary depending on whether the State is under Integrated Safeguards or the facility under a Site or State-Level Approach (SLA)

*Other Important Safeguards Terms and Concepts**

**(Source – IAEA Safeguards Glossary and INFCIRC/153)*

(Note that definitions are paraphrased – see the Glossary for more details)

Nuclear Material Balance Area (MBA)

- An area in or outside of a facility such that the quantity of each nuclear material transfer and the physical inventory can be determined for the purpose of establishing a nuclear material balance

Key Measurement Point (KMP)

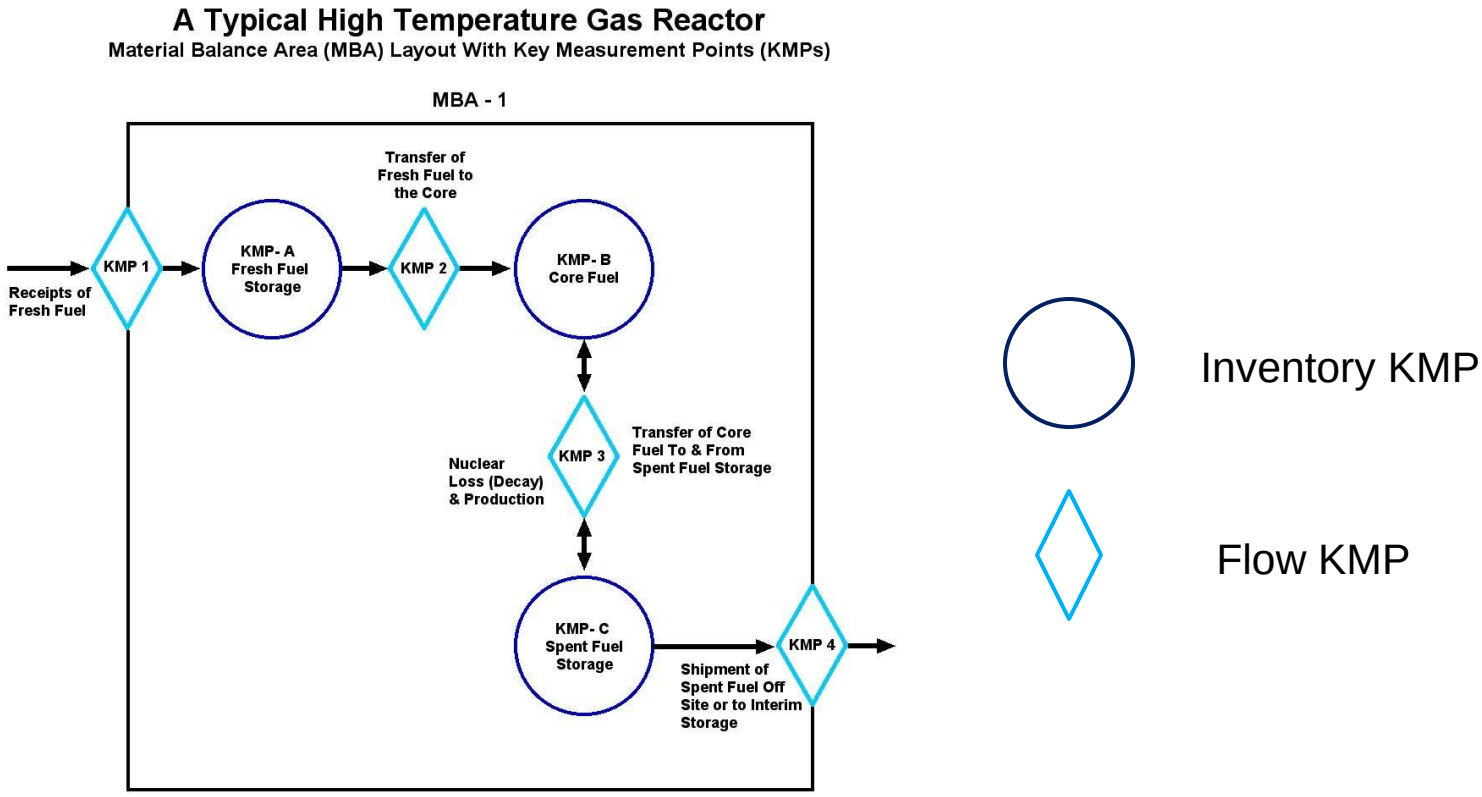
- A location where nuclear material can be measured to determine nuclear material flow or inventory
- The former is called a Flow-KMP and the latter an Inventory-KMP

Strategic Point

- Are locations other than KMPs that are considered strategically important by the IAEA for implementing safeguards in the facility
- They are selected during review and examination of the facility design information and may include containment and surveillance and sampling/assay locations

Nuclear Material Balance Area (MBA) and Key Measurement Points (KMPs)

(Source – Report INL/EXT-10-17981, 2009)



*Other Important Safeguards Terms and Concepts**

**(Source – IAEA Safeguards Glossary and INFCIRC/153)*

Nuclear Material Accountancy

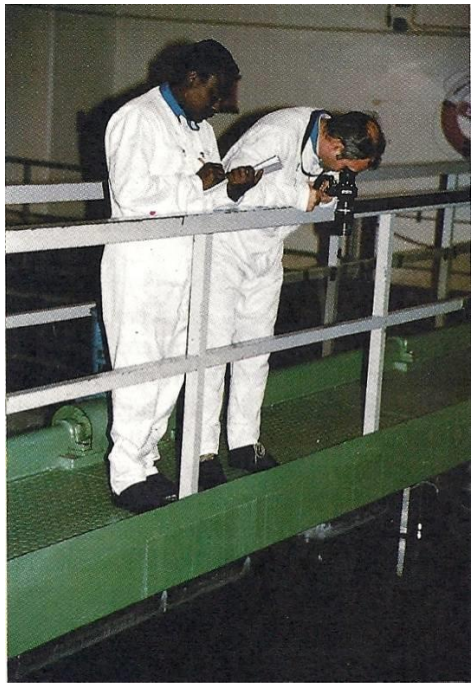
- The practice of nuclear material accounting, as implemented by the Facility Operator and the State System of Accounting for and Control of Nuclear Material (SSAC), that satisfies the requirements in the Safeguards Agreement between the State and the IAEA
- Is used to independently verify the correctness of the information in the Facility Operator's Records and the State Reports submitted by the SSAC to the IAEA
- Remains the safeguards measure of fundamental importance (as per INFCIRC/ 153)
- Is based on the declaration of nuclear material and activities made by the Facility Operator
- The Facility Operator's declarations are verified by the IAEA using inventory taking and statistically based random sampling during inspections
- Verification techniques include: Destructive Analysis (DA), Non-Destructive Analysis (NDA), etc.
- More will be said about this technology in the subsequent presentation

Nuclear Material Accountancy (The Short Version)

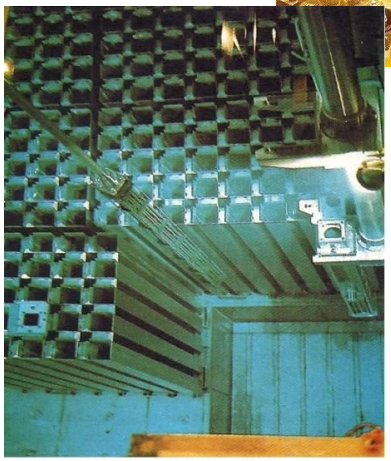
- Is the foundation of (Facility-Level or Traditional) IAEA Safeguards
- The IAEA monitors and verifies the State's declared nuclear material
- This is done per the Safeguards Agreement
- The State (SSAC) declares nuclear material inventories and inventory changes at facilities to the IAEA
- The IAEA verifies the State's and Facility Operator's declarations through safeguards inspections
- The IAEA verifies these declarations using Traditional Safeguards Techniques
  - Bookkeeping (Audit of Records and Reports)
  - Verification of Nuclear Material Inventory and Changes
  - Containment and Surveillance (to support Accountancy)
  - Other Measures as required

Nuclear Material Accountancy - Inspection and Nuclear Material Verification

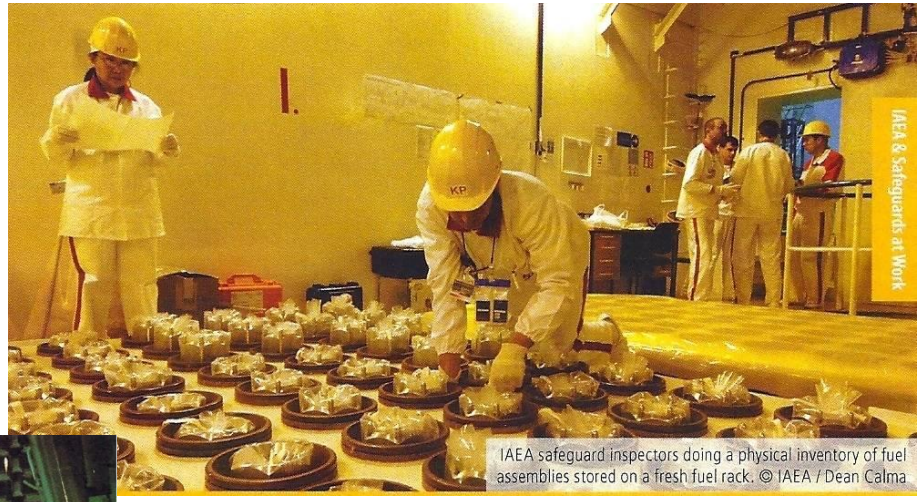
(Source – IAEA, ca. 2008)



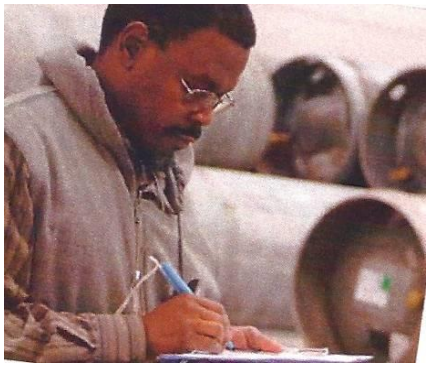
IAEA Inspectors Using CVD



Ringhals PWR Storage Racks



IAEA safeguard inspectors doing a physical inventory of fuel assemblies stored on a fresh fuel rack. © IAEA / Dean Calma



*Other Important Safeguards Terms and Concepts**

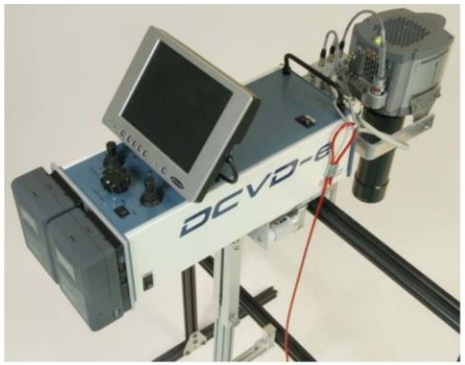
**(Source – IAEA Safeguards Glossary and INFCIRC/153)*

Nuclear Material Accountancy – Nuclear Material Verification

- For the purpose Verifying Inventory and Inventory Changes nuclear material is sorted into strata
- Nuclear material strata are further sorted into items(if possible) and batches
- Verification involves identifying the material and verifying the amount, i.e. counting items, identifying items, or measuring the bulk (mass/volume)
- Samples are taken for Destructive or Non-Destructive Assay (DA and NDA), using statistically based sampling to verify the material type and quantity
- Samples may be collected for DA and shipped to the Safeguards Analytical Laboratory (SAL) near Vienna (NWAL-NetWork of Analytical Laboratories)
- Non-Destructive Assay is performed on location and often includes:
  - Verification of the Cerenkov Light (for spent fuel)
  - Active/Passive Coincidence Neutron Counting &
  - Gamma Ray Spectroscopy (for U-235 and Pu mass determination)

Nuclear Material Verification Systems

(Sources – IAEA, AECL, Channel Systems, ICXT, Bot Engr., and Canberra, 2009)



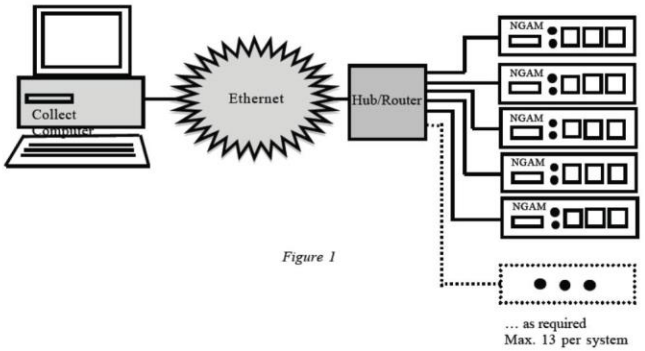


Figure 1

*Other Important Safeguards Terms and Concepts**

**(Source – IAEA Safeguards Glossary and INFCIRC/153)*

Containment and Surveillance (C/S)

- Complements Nuclear Material Accountancy
- Includes nuclear material containment (seal), video surveillance, and related systems
- Maintains the continuity-of-knowledge (CofK) of safeguarded nuclear material and safeguards systems
- Are used as tampering indicating systems – i.e. to detect tampering with the nuclear material or safeguards system or detect undeclared nuclear material movements
- The enclosure/vault and seal wire/cable are integral parts of the containment system – their integrity must be assessed and ensured
- The seal and video surveillance has to be reviewed and evaluated by an inspector to draw a safeguards conclusion
- More will be said about safeguards equipment and systems in the subsequent presentation

Containment and Surveillance (C/S) Systems

Other Important Safeguards Terms and Concepts*

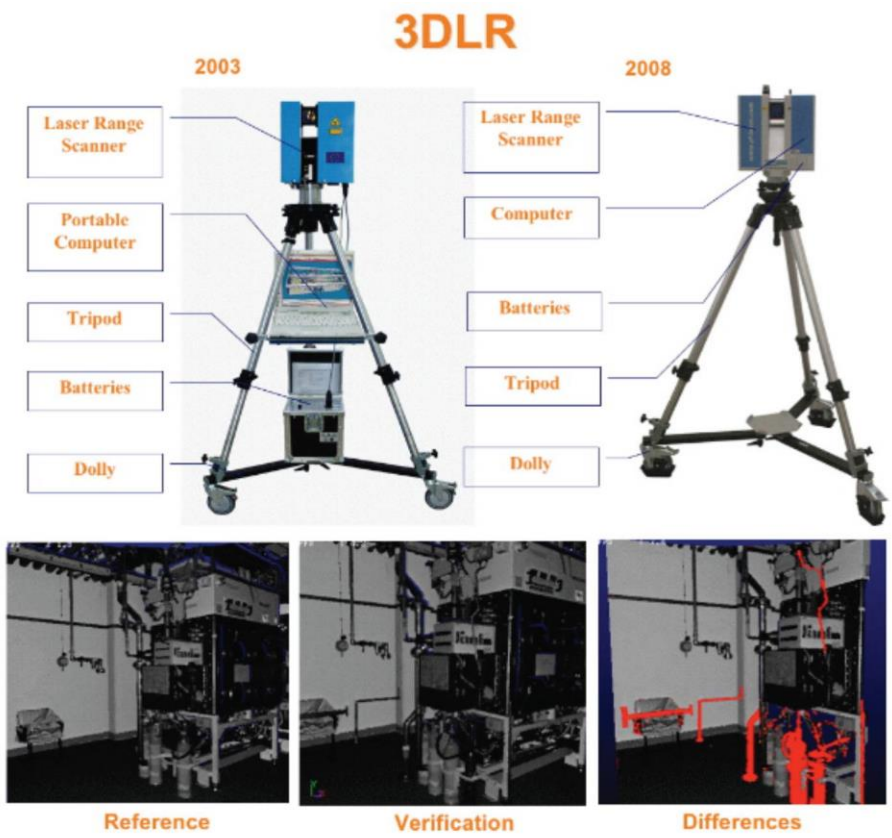
(Source – IAEA Safeguards Glossary and INFCIRC/153)

Design Information Examination and Verification

- Design Information is…"information concerning nuclear material subject to safeguards under the agreement and the features of facilities relevant to safeguarding such material"
- Design Information (DI) must be provided by the State (SSAC) to the IAEA when a decision is officially made to construct a nuclear facility
- The State submits design information in the form of a completed IAEA Design Information Questionnaire (DIQ)
- The IAEA verifies this information by performing Design Information Examination and Verification (DIE/DIV)
- The purpose of DIE/DIV is to confirm that the nuclear facility is as declared by the State – i.e. that its function or capacity has not been altered
- IAEA inspectors use the Facility DIQ, design drawings, visual observation, hand tools, and the 3DLR to perform DIE/DIV

Design Information Examination and Verification 3-Dimensional Laser Range Finder (3DLR)

(Source – European Commission JRC-Ispra, 2009)



Other Important Safeguards Terms and Concepts*

(Source – IAEA Safeguards Glossary and INFCIRC/153, paraphrased)

Discrepancy

- An Inconsistency between the Inspector's Observation and the Facility Operator's Records and/or State Reports

Anomaly

- A Discrepancy involving more than 1 SQ of nuclear material
- Denial or restriction of IAEA access for Inspection
- Undeclared safeguards significant changes to the facility or operation

Material Balance Equation and Material Unaccounted For (MUF)

MUF = Physical Beginning + Increases – Decreases – Physical Ending Inv.

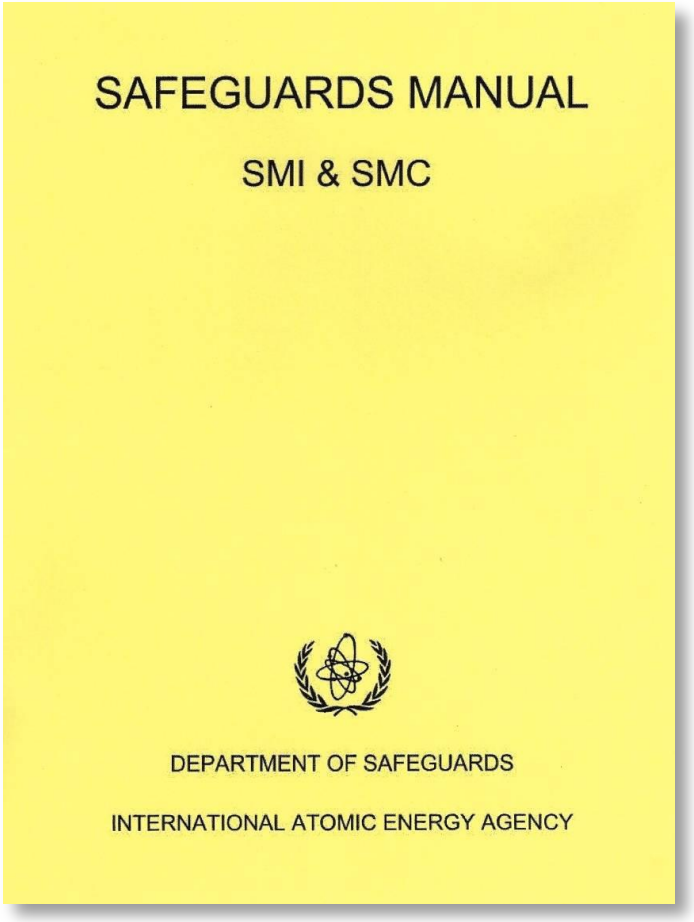
- MUF for an "Item Facility" (e.g. Nuclear Power Plant) should be zero, because the nuclear material is present in integral form (fuel assemblies) and can be counted
- MUF for a "Bulk Facility" will likely be non-zero (e.g. Fuel Fab Plant), due to the uncertainty in measuring bulk nuclear material, or other factors
- The size of the MUF (and Cumulative MUF) may indicate the protracted diversion of nuclear material - Trend Analysis

IAEA Safeguards Manual and Criteria

(Internal IAEA Document)

- At the Facility Level, the IAEA Safeguards Manual Safeguards Criteria (Part- SMC) defines the:
  - Inspection Frequency
  - Nuclear Material Verification Requirements (i.e. Detection Probability)
  - Other Requirements for meeting IAEA Safeguards Objectives
- The Criteria is divided into Facility Specific Sections with Supporting Appendices
  - Light Water Reactors
  - On-Load Refueled Reactors (CANDU)
  - Other Reactors (FBR and HTGR)
  - Research Reactors and Critical Assemblies
  - Uranium Conversion and Fuel Fabrication
  - MOX/HEU Fuel Fabrication
  - Uranium Enrichment
  - Spent Fuel Reprocessing
  - Storage
  - Other and Locations Outside Facilities (LOFs)

IAEA Safeguards Manual and Criteria



*IAEA Safeguards Manual and Criteria**

Key Points Covered in the Criteria: (For each Type of Facility)

- Examination of Operating Records and State Reports
- Physical Inventory Verification (PIV)
- Verification of Domestic/International Transfers and Inventory Changes
- Verification at Other Strategic Points (OSP)
- Confirmation of the absence of Nuclear Material Borrowing
- Nuclear Material Balance Evaluation
- Interim Inventory Verification (IIV - for Timely Detection)
- Safeguards Discrepancy and Anomaly Follow-up
- Verification of Design Information (DIE/DIV)
- Verification of the Facility Operator's Measurement System
- Confirmation of Nuclear Material Transfers
- Activities related to Equipment and Facilities under Safeguards
- etc. *(See the Criteria for more details)

GOOD SAFEGUARDS:
What It Takes To Avoid Being Fooled?

Good safeguards: Complete set of interrelated measures covering all credible diversion paths– with some unpredictability.

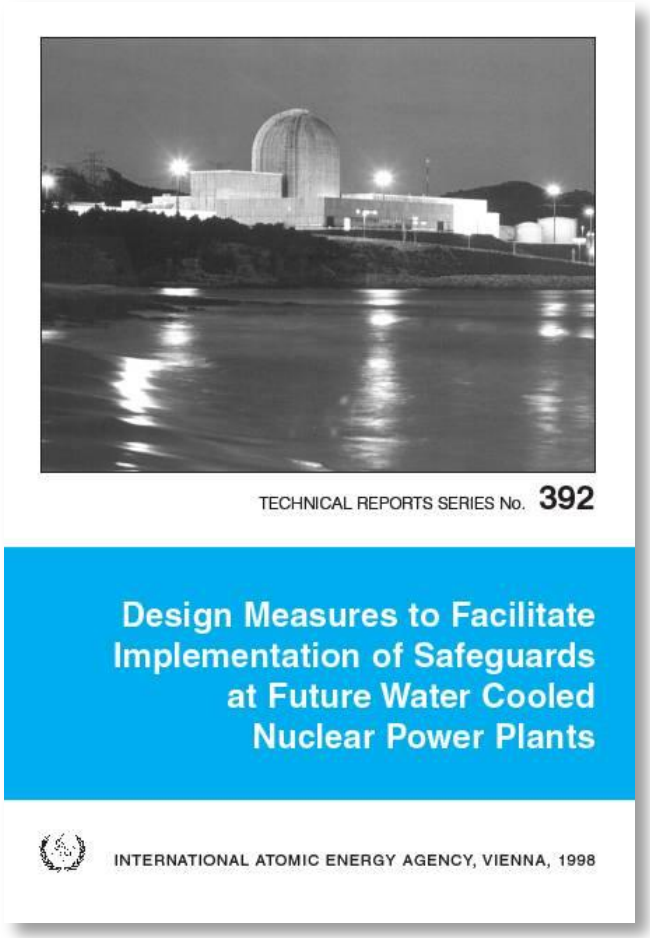
- **Fudge the books** → ***Records & Reports, Source docs; transit matching***
- **Take a bit at a time** → ***Bias defects***
- **Take some at a time** → ***Partial defects***
- **Substitute a dummy** → ***Gross defects***
- **Present the same material** → ***Containment/Surveillance***
- **Get around C/S** → ***Remeasurement, Authentication***
- **Bring in other material** → ***Borrowing measures***

IAEA Technical Reports – For Additional Guidance

- The IAEA periodically issues Technical Reports to help Facility Operators and States implement safeguards more efficiently
- Many of these focus on types of facilities
- An example is IAEA Technical Report No. 392 (1998)
- This report deals with the Design Measures to Facilitate the Implementation of Safeguards at Future Water Cooled Nuclear Power Plants
- There are over 442 Nuclear Power Plants operating in the world
- This is one of the largest categories of nuclear facilities under IAEA safeguards
- This document provides insight regarding the:
  - IAEA Safeguards Objectives at a Water Cooled Reactor
  - Design Information Required
  - Generalized IAEA Safeguards Approach
  - Containment (Seal) Systems utilized
  - Video Surveillance Systems utilized
  - etc.

IAEA Technical Reports

Example of Technical Report No. 392

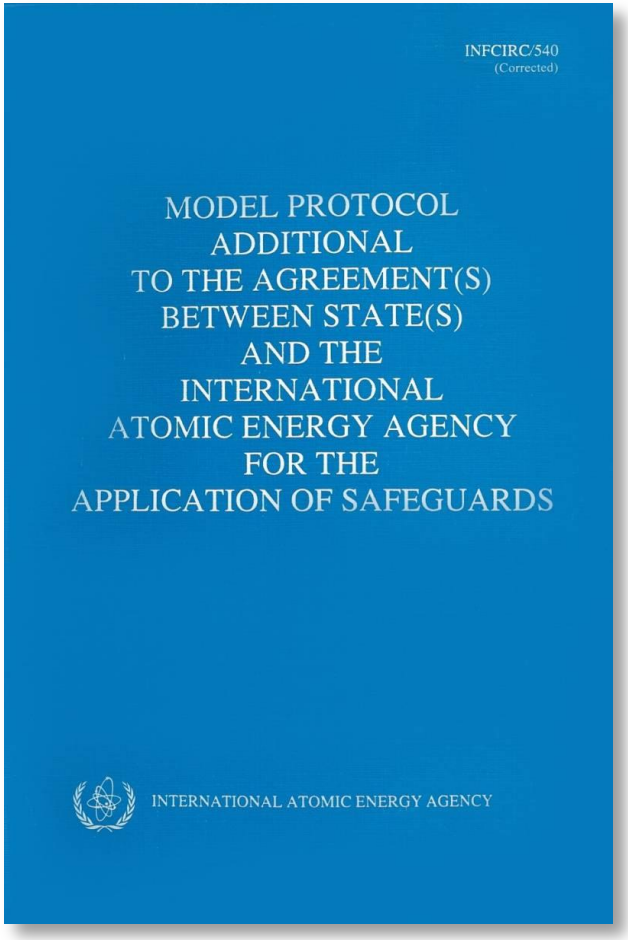


Facility-Level Safeguards and the Additional Protocol

- To strengthen the Safeguards Regime, the IAEA and its Member States developed an Additional Protocol (AP) to the Safeguards Agreement
- The standard text of the Additional Protocol is IAEA INFCIRC/540 (corrected)
- The AP is an Addendum to the State's Safeguards Agreement with the IAEA – (for the United States this is INFCIRC/288/Add.1)
- Implementation is voluntary
- It provides for :
  - Access to Information concerning the complete nuclear fuel cycle in the State, from mines to waste
  - Complementary Access to sites, facilities, and locations in the State
  - Use of Visual Observation, Radiation Detection, and Environmental Sampling (ES) to detect potential undeclared nuclear material and activities in the State
- IAEA inspectors may perform Complementary Access at the facility, thereby enhancing safeguards at the Facility and the State as a whole
- The Additional Protocol will be discussed in more detail in a subsequent Presentation

The Additional Protocol

IAEA INFCIRC/540 (corrected)



Summary

- Facility-Level IAEA Safeguards are based fundamentally on the Safeguards Agreement between the State and the IAEA
- This Safeguards Agreement is typically an INFCIRC/153-type agreement
- The over-arching objective of IAEA Safeguards is the timely detection of the possible diversion of significant quantities of nuclear material
- The IAEA Safeguards Manual and Criteria (Part-SMC) define the facility inspection frequency and nuclear material verification requirements - based on the type of nuclear facility and nuclear material
- The Safeguards Criteria is fundamental in developing the State-Level Safeguards Approach (SLA) – although verification requirements may differ from those specified in the Criteria
- The would-be IAEA Analyst and Safeguards Inspector needs to understand how nuclear safeguards are implemented at the Facility Level – in order to understand safeguards in the State as a whole
- IAEA Safeguards have been strengthened through the adoption of an Additional Protocol (INFCIRC/540) to most Safeguards Agreements, which also enhances Facility-Level Safeguards

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