LA-UR-17-28351

Title: IAEA Sampling Plan

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Intended for: Training Course

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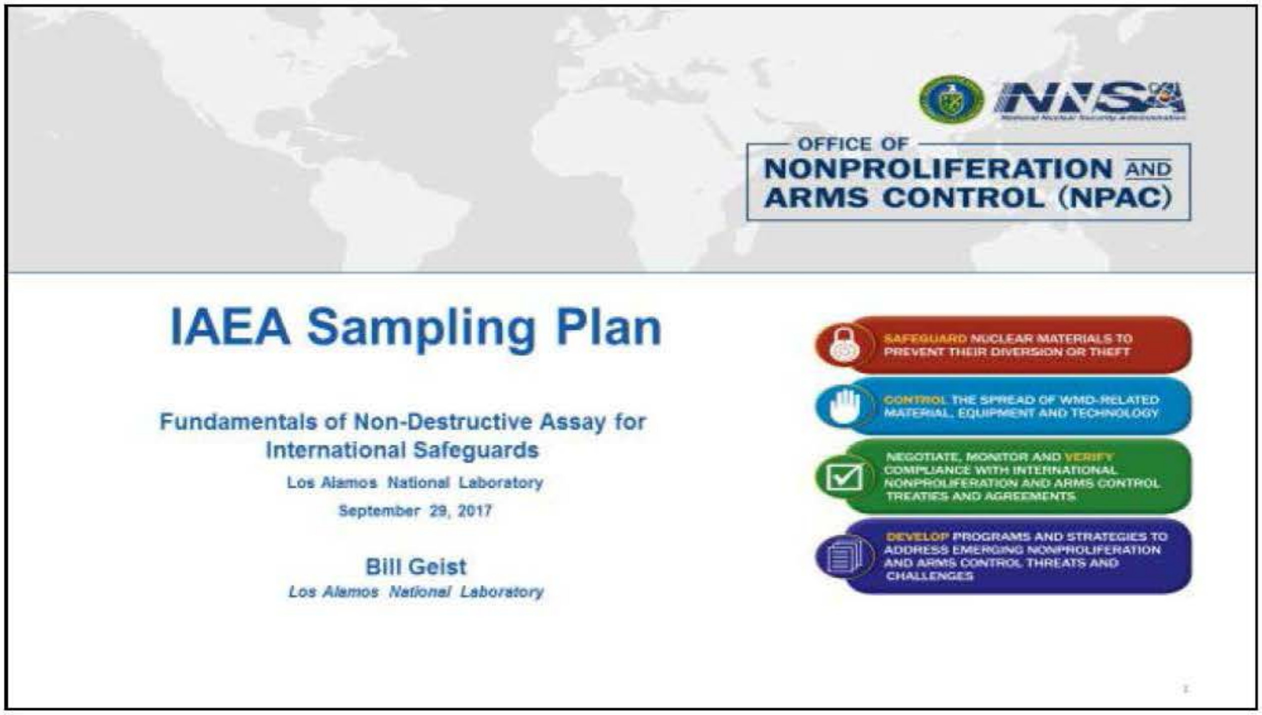

OFFICE OF
NONPROLIFERATION AND ARMS CONTROL (NPAC)
IAEA Sampling Plan
Fundamentals of Non-Destructive Assay for International Safeguards
Los Alamos National Laboratory
September 29, 2017
Bill Geist
Los Alamos National Laboratory
SAFEGUARD NUCLEAR MATERIALS TO PREVENT THEIR DIVERSION OR THEFT
CONTROL THE SPREAD OF WMD-RELATED MATERIAL, EQUIPMENT AND TECHNOLOGY
NEGOTIATE, MONITOR AND VERIFY COMPLIANCE WITH INTERNATIONAL NONPROLIFERATION AND ARMS CONTROL TREATIES AND AGREEMENTS
DEVELOP PROGRAMS AND STRATEGIES TO ADDRESS EMERGING NONPROLIFERATION AND ARMS CONTROL THREATS AND CHALLENGES

Estimated Module Duration: 30 minutes

Required Tools and Materials:

1. Projector, screen, laptop with Word and PowerPoint programs
2. Participant guides, with slides and supplemental material

References:

1. INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Safeguards Glossary, International Nuclear Verification Series No. 3, IAEA, Vienna (2003). http://www-pub.iaea.org/books/IAEABooks/6570/IAEA-Safeguards-Glossary
2. INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Safeguards Technical Manual, Part F Statistical Concepts and Techniques, Volume 3, IAEA-TECDOC-261, IAEA Vienna (1982). http://www-pub.iaea.org/MTCD/publications/PDF/te_261_web.pdf

Supporting Documents:

1. None

Job Aids:

1. None

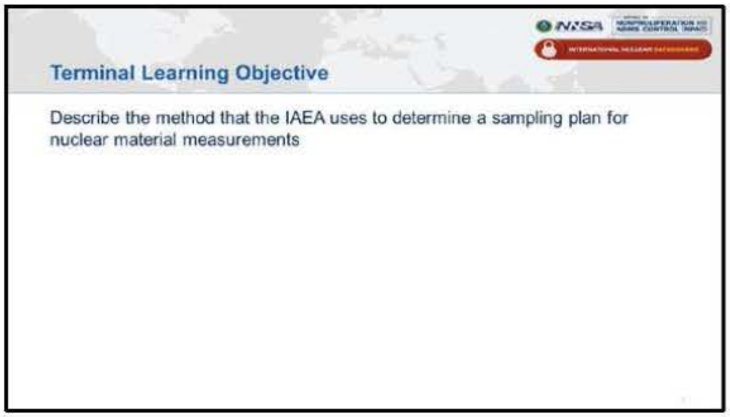
Terminal Learning Objectives (TLOs):

- TLO-1: Describe the method that the IAEA uses to determine a sampling plan for nuclear material measurements

Enabling Learning Objectives (ELOs):

- ELO-1: Describe the terms detection probability and significant quantity
- ELO-2: List the three nuclear material measurement types
- ELO-3: Describe the sampling method applied to an item facility
- ELO-4: Describe multiple method sampling

Additional Information for Students:

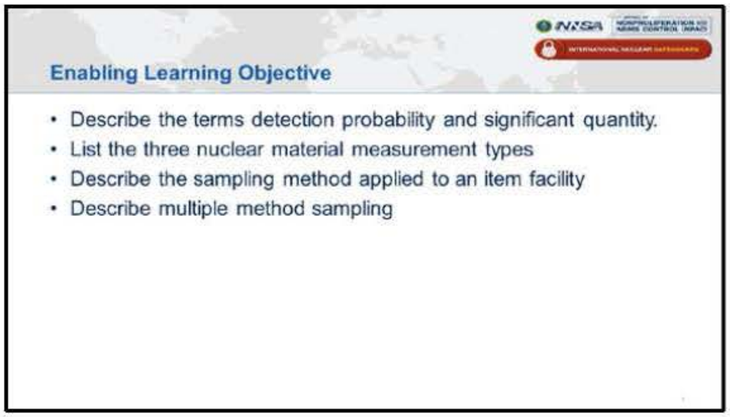


Instructor Notes:

Review learning objectives with the participants.

Encourage participants to ask questions during the lecture.

Additional Information for Students:



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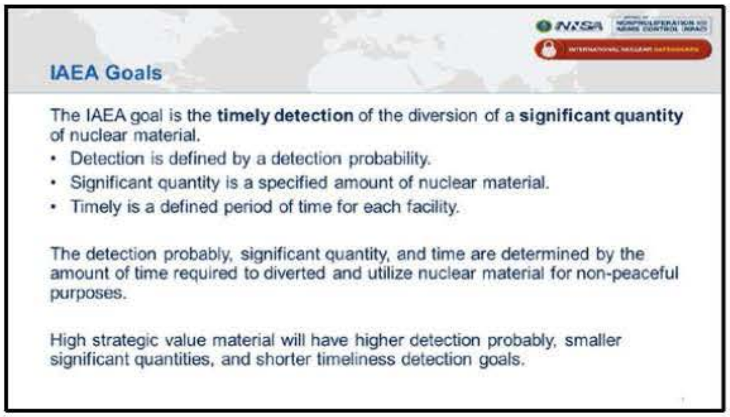


The primary objective of IAEA safeguards is the timely detection of the diversion of a significant quantity of material and the timely detection of undeclared activities.

Instructor Notes:

Detection probably and significant quantity are defined in the following slides. The detection time is the maximum time that may elapse between diversion of a given amount of nuclear material and the detection of that diversion by IAEA safeguards activities. Detection times normally will correspond to the estimated conversion times. Longer detection times may be acceptable in a State where the additional protocol is in force and/or in States where the IAEA has drawn and maintained a conclusion of the absence of undeclared nuclear material and activities.

Additional Information for Students:

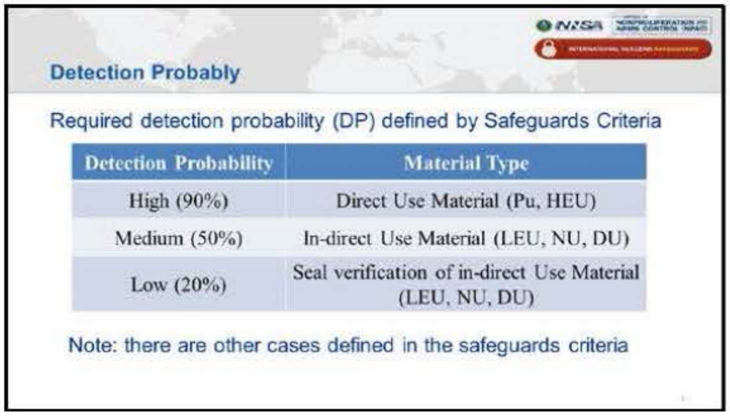
Type of Material	Significant Quantity
Pu	8 kg
HEU	25 kg U-235
LEU	75 kg U-235
Natural U	10 tones
Depleted U	20 tones
Th	20 tones

Approximate quantity required for a single nuclear explosive device. Significant quantity is defined as the approximate quantity of nuclear material in respect of which, taking into account any conversion process involved, the possibility of manufacturing a nuclear explosive device cannot be excluded.

Instructor Notes:

Significant quantity (SQ) is the approximate amount of nuclear material for which the possibility of manufacturing a nuclear explosive device cannot be excluded. Significant quantities take into account unavoidable losses due to conversion and manufacturing processes and should not be confused with critical masses. Significant quantities are used in establishing the quantity component of the IAEA inspection goal. Significant quantity values currently in use are given in the table.

Additional Information for Students:

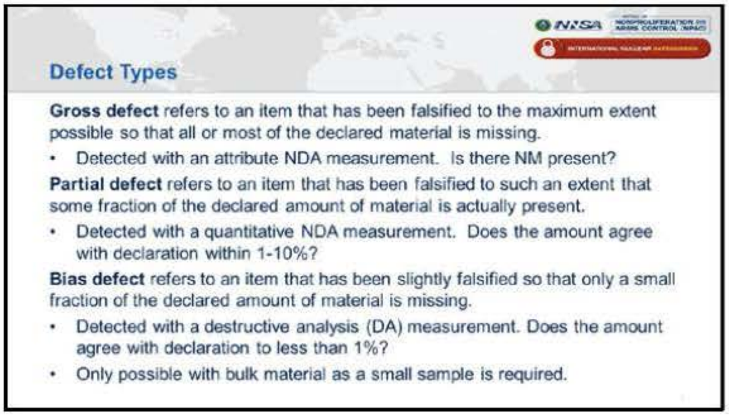


Detection Probability is defined as the assurance given by safeguards measures expressed as the overall probability of detecting the absence of a specified quantity of nuclear material.

Instructor Notes:

Detection Probability: The probability, if diversion of a given amount of nuclear material has occurred, that IAEA safeguards activities will lead to detection. The detection probability for safeguards activities involving nuclear material accountancy can be quantified, and the accountancy detection probability is preselected as in input parameter for establishing sampling plans. The values currently in use are 90% for 'high' and 20% for 'low' probability levels.

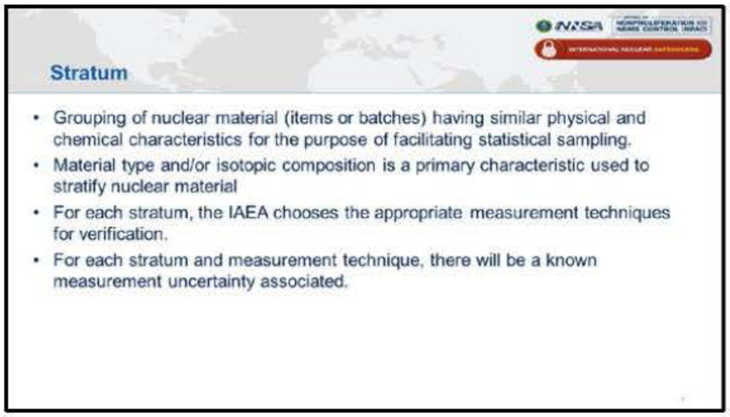
Additional Information for Students:



Defect is defined as the difference between the declared amount of nuclear material and the actual amount present. The IAEA defines three types of defects.

Instructor Notes:
Explain different types of defects.
Gross Defect: an item that has been falsified to the maximum extent possible, i.e., all of the nuclear material is missing.
Partial Defect: refers to a difference between the amount of nuclear material actually present in an item and the amount declared to be present, which is a fraction of the declared amount.
Bias Defect: refers to a difference between the amount of nuclear material actually present in an item and the amount declared to be present, which is a fraction of the declared amount, determined by the most precise measurement available.

Additional Information for Students:

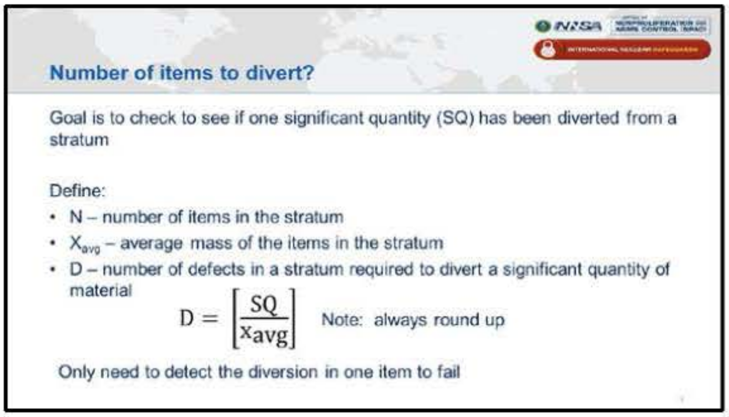


Monitoring of a stratum, a group of nuclear material items that have similar chemical and physical parameters, can be achieved by verifying a randomly selected sample of items from the stratum. The number of nuclear material items to be verified from the stratum (the sample size) should be calculated using the IAEA sample plan.

Instructor Notes:

Definition of Stratum: a grouping of items and/or batches having similar physical and chemical characteristics (e.g. isotopic composition) made for the purpose of facilitating statistical sampling. The desired end result of stratification is that the items in a particular stratum are more like one another with respect to certain characteristics relevant for verification measurement and safeguards data analysis purposes than they are like the items in the other strata. In practice, a stratum may contain dissimilar materials as long as the facility operator used one method for measurement and the inspector used one method for verification (not necessarily the same). Stratification simplifies verification, making it possible to formulate the sampling plans needed to verify a material balance and to calculate its uncertainty (sigma MUF). The operator and the IAEA should cooperate in defining strata so that the purposes of stratification are met.

Additional Information for Students:

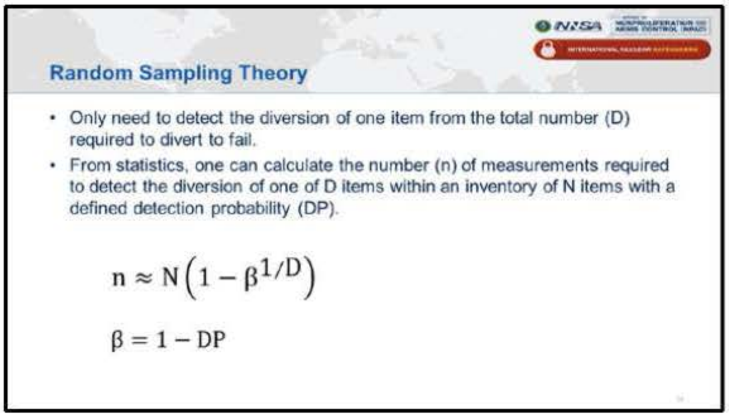


The IAEA is looking for the diversion of one significant quantity. If all the material is replaced with dummy material, then D is the minimum number of items needed to divert one significant quantity. An inspection will fail if the IAEA cannot verify one single item.

Instructor Notes:

Using this equation, one can calculate the minimum number of items that must be falsified to divert one SQ of material.

Additional Information for Students:



Random sampling theory tells us how many items (n) that we need to measure to detect one of the diverted items (D) with a given detection probably.

Instructor Notes:

Sample size (n) is the number of items to be verified in order to be able to draw conclusions about the population (N) from which the sample is taken. In the context of IAEA safeguards the formula is used for estimating the total number of samples to take from the stratum. The total sample size (n) may be allocated among several IAEA verification measurements (gross, partial, and bias defects). The formula approximates the sample size that would result from application of the hypergeometric probability distribution (sampling without replacement).

Additional Information for Students:

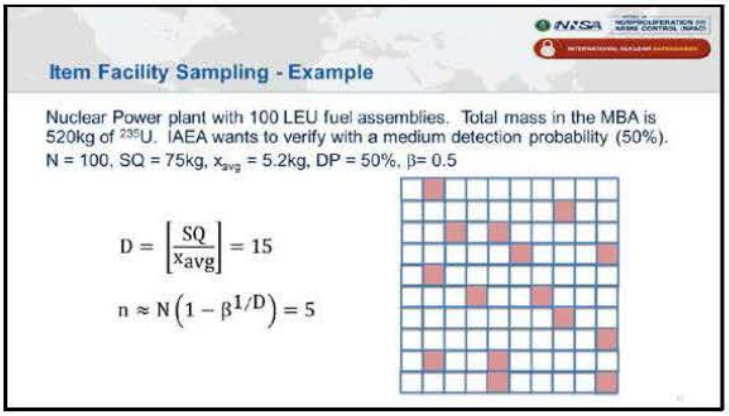
The IAEA categorizes nuclear facilities into two types. Item facilities where nuclear material is contained in discrete items. A bulk facility is where nuclear material is found in bulk form. Often bulk facilities have nuclear material in both bulk and item form.

Instructor Notes:

Item Facility is a facility where all the nuclear material is kept in item form and the integrity of the item remains unaltered during its residence at the facility. In such cases, IAEA safeguards are based on item accountancy procedures (e.g. item counting and identification, non-destructive measurements of nuclear material and the verification for the continued integrity of the items). Examples of item facilities are most reactors and critical assemblies and storage installations for reactor fuel.

Bulk Facility is a facility where nuclear material is held, processed or used in bulk form. Where appropriate, bulk handling facilities may be organized for safeguards purposes into multiple material balance areas, for instance by separating activities relating only to the storage and assembly of discrete fuel items from those involving storage or processing of bulk material. In a bulk MBA, flow and inventory values declared by the facility operator are verified by the IAEA through independent measurements and observation. Examples of bulk handling facilities are plants for conversion, enrichment, fuel fabrication and spent fuel reprocessing, and storage facilities for bulk material.

Additional Information for Students:

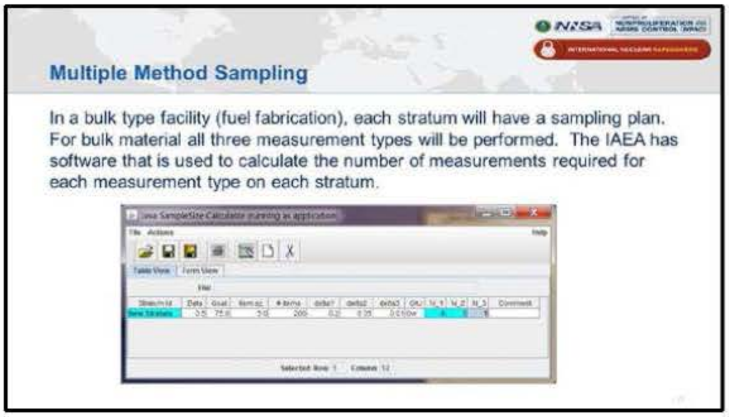


In Item facilities the only diversion scenario is to replace items with dummy items. In this case, the sample plan is determined using the random sampling theory.

Instructor Notes:

Shown is an example of a sampling plan for an item facility. Under these conditions, the IAEA would randomly choose 5 items and perform a gross NDA measurement to verify the presence of nuclear material. In addition the IAEA would perform item counting of all the nuclear material items.

Additional Information for Students:

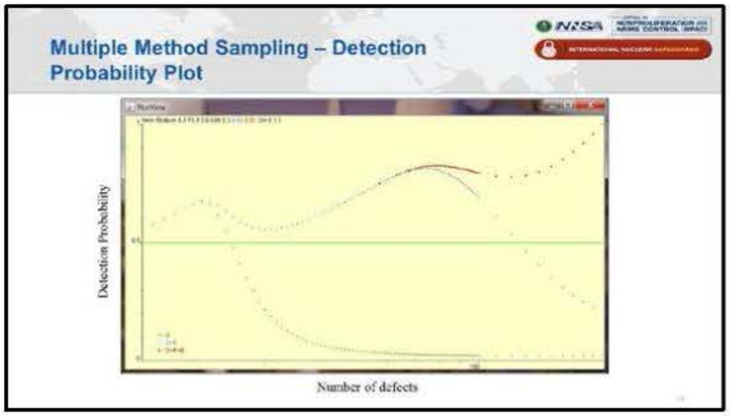


In Bulk facilities, the nuclear material is found in bulk form and the diversion scenarios include removing all the material, part of the material, or a very small amount of material. The sampling plan for bulk facilities will include gross, partial and bias defect measurement techniques. The IAEA has software that inspectors can use to determine the number of difference measurement needed to be performed to satisfy the detection probability.

Instructor Notes:

Shown in the software that the IAEA runs to calculate the multiple method sampling plan. In this example the DP is 50%, SQ = 75 kg (assumes LEU), average item size is 5kg, and number of item is 200. Partial defect uncertainty is 5% and bias defect uncertainty is 1%. To achieve a 50% DP requires, 6 Gross defect measurements, 3 partial defect measurements, and one bias defect measurement.

Additional Information for Students:



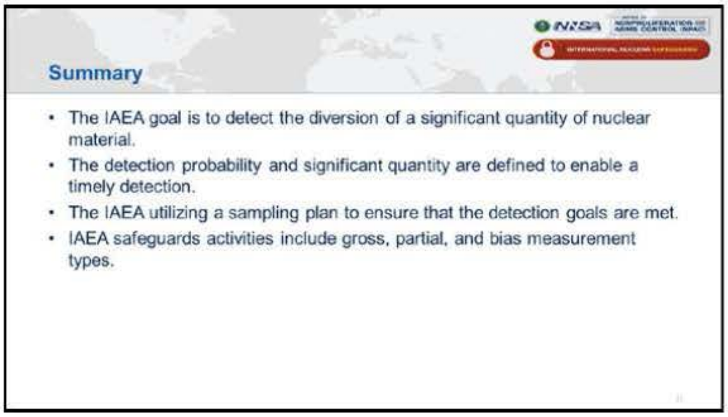
The IAEA sampling plan software calculates the detection probability versus the number of items with defects.

Instructor Notes:

Plot view will plot detection probabilities for the stratum currently selected in the Table or Form view as a function of the number defects in it. An example of the Plot View is shown in the picture. In this example the DP is 50%, SQ = 75 kg (assumes LEU), average item size is 5kg. Partial defect uncertainty is 5% and bias defect uncertainty is 1%.

The number of defects is calculated assuming that 1SQ of the material is missing in the stratum. So, in the example above, the minimum number of defective items is 15, when defect size is 100%, and the maximum number of defects is always equal to the total number of items in the stratum. The logarithmic scale is used for the X-axis of the plot.

Additional Information for Students:



IAEA uses a sampling plan to determine the number and type of measurements necessary to ensure that a significant quantity of nuclear material has not been diverted from peaceful nuclear activities.

Instructor Notes: