Experience with Nuclear Inspector Training at JRC, Ispra

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Safeguards inspector training at Ispra:

More than 20 years training in the Nuclear Security Unit, JRC Ispra, ITU

More than 1050 trainees

Basis:

- PERLA Laboratory as nuclear infrastructure with nuclear material
- TAME and Seals lab as non-nuclear infrastructure
- Teams of experienced trainers for nuclear and non-nuclear work

Training is embedded in R&D and support for nuclear safeguards and security for EURATOM, IAEA, EC
A. Aim of nuclear safeguards inspector training:

Give nuclear material inspectors insight into the safeguards system as a whole.

Make them understand nuclear safeguards as a system of many elements:
- owner declarations
- verification measurements
- bookkeeping
- statistical data evaluation
- item identity verification
- containment and surveillance
- site verification
- observation of any particularities in the inspection

They must understand their role in this system
Aim of nuclear safeguards inspector training

Explain the roles of
- **direct** verification methods for nuclear material and
- **indirect** methods as containment and surveillance.

Provide background knowledge on the
- **technical system of the nuclear fuel cycle** and
- **strengths and weaknesses** of inspection measurement methods.
  (What can I see, what can I not see?)

Provide inspectors with the **practical** skills with (standard)
instrumentation and methods
- to verify the presence of nuclear material,
- qualitatively and quantitatively.

Exercise the **decision making** after measurement
  (e.g. to give the statement: "This material is not as declared!" )
For comparison:

Aim of nuclear borderline officer training:

The duty is
- to discover nuclear material and
- to react according to the rules.

Another type of training is required.
B. Trainees

- **Newcomers:**
  
  - Dentist
  - Nuclear physicist
  - Nuclear engineer
  - Captain / fishery inspector
  - Civil engineer
  - Mathematician
  - From European administration

- **Experienced inspectors**

- **Inspectors who change the field of inspection**
C. Training types

Course types

- Systematic sequence of courses (IAEA: 14 week ICAS course for beginners)

- One week laboratory courses on standard methods (U enrichment, e.g.)

- In-field training (spent fuel)

- One day training modules at head quarter (before mission)
C. Training types

The course type depends on

- contents
- participants
- training location
- training means

Participants

- Newcomer need introductions and basic knowledge
- Experienced inspectors need refreshment every 5 (?) years
- New methods need to be explained to the inspectors for the site
Training types

Training places

- Theory in class
- Laboratory exercises
- In-field training

Training means

- Nuclear material
- Laboratory
- Instrumentation
- Printed matter (textbooks)
- PC based training tools
- Trainers with experience
Which type of training is the ideal one, for the contents and the trainees?

There is no ideal type.

A variety of course types is required.

Course contents must adapt to the knowledge of the trainees.

Courses must follow the development of the safeguards system and of the instrumentation.
For newcomers after recruitment:

General introduction by EURATOM or IAEA at headquarters in class

Politics,
law,
nuclear material,
nuclear fuel cycle,
safeguards system,
safeguards inspections,
rules for inspectors,
safety,
radiation protection,
etc.
D. Safeguards Training at JRC, Ispra

A variety of course types is offered

Stress on NDA methods and containment and surveillance

1. Preparatory course
2. Systematic basic NDA laboratory courses - PERLA
3. Advanced / special laboratory courses - PERLA

4. Measurement techniques for liquids - TAME
5. 3D Laser-based Design Information Verification – 3D laboratory
6. JRC CANDU Sealing System (JCSS)

7. Special instrument courses
1. Preparatory course - Luxembourg

**NDA basic physics**, esp. for new inspectors, now outsourced

Experience: Inspectors need to learn what measurements can do and what they cannot do – their own strengths and weaknesses

2. Main laboratory courses - PERLA

**U enrichment determination by gamma spectrometry**

**Pu isotopic composition determination by gamma spectrometry**

**Active neutron interrogation**

**Passive neutron assay**

Experience: These courses were essential for many inspectors
3. Advanced / special courses - PERLA

**Pu physical inventory verification**
bring things together: Statistics, inspection planning, qualitative and quantitative measurements

**Advanced hands-on RADAR/CRISP/XSEAT**
bring things together: Automatic measurement stations, informatics tools, data collection, data evaluation, inspection report

(Statistics)

Experience: Good for motivation of experienced inspectors
4. Measurement techniques for liquids - TAME:

Mass/volume Methodology

Solution Monitoring Evaluation Systems

Advanced hands-on DAI

5. 3D Laser-based Design Information Verification – 3D laboratory
6. JRC CANDU Sealing System (JCSS)

7. Courses on single instruments or measurement objects

   JRC waste drum monitor

   AWCC for FRM-II fuel element
On special request, e.g. for IAEA:

- Advanced NDA for experienced inspectors
- Pu Diversion Verification
- Site verification

Experience: Good for motivation of experienced inspectors

Around 14 sessions per year in total

Training schedule:
## Inspector Training at JRC Ispra

<table>
<thead>
<tr>
<th>Course</th>
<th>Place</th>
<th>Week</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>Passive neutron assay</td>
<td>PERLA</td>
<td>10</td>
<td>07 - 11 March</td>
</tr>
<tr>
<td>U enrichment determination by gamma spectrometry</td>
<td>PERLA</td>
<td>12</td>
<td>21 - 25 March</td>
</tr>
<tr>
<td>Pu isotopic composition by gamma spectroscopy</td>
<td>PERLA</td>
<td>14</td>
<td>04 - 08 April</td>
</tr>
<tr>
<td>JRC CANDU sealing system</td>
<td>Building 73</td>
<td>19</td>
<td>11-12 May</td>
</tr>
<tr>
<td>Advanced Hands-on RADAR/CRISP/XSEAT</td>
<td>PERLA</td>
<td>20</td>
<td>16 - 20 May</td>
</tr>
<tr>
<td>Data Analysis and Interpretation</td>
<td>TAME</td>
<td>21</td>
<td>23 - 27 May</td>
</tr>
<tr>
<td>Tank calibration</td>
<td>TAME</td>
<td>23</td>
<td>06 - 10 June</td>
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<tr>
<td>U enrichment determination with MGAU</td>
<td>Luxembourg</td>
<td>34</td>
<td>25 - August</td>
</tr>
<tr>
<td>Data Analysis and Interpretation</td>
<td>TAME</td>
<td>40</td>
<td>03 - 07 Oct</td>
</tr>
<tr>
<td>Pu isotopic composition by gamma spectroscopy</td>
<td>PERLA</td>
<td>42</td>
<td>17 - 21 Oct</td>
</tr>
<tr>
<td>U enrichment determination by gamma spectrometry</td>
<td>PERLA</td>
<td>45</td>
<td>07 - 11 Nov</td>
</tr>
<tr>
<td>3D Laser Based Verification System</td>
<td>3D Laboratory</td>
<td>45</td>
<td>07 - 11 Nov</td>
</tr>
<tr>
<td>Active neutron interrogation</td>
<td>PERLA</td>
<td>46</td>
<td>14 - 18 Nov</td>
</tr>
<tr>
<td>Passive neutron assay</td>
<td>PERLA</td>
<td>47</td>
<td>21 - 25 Nov</td>
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## Inspector Training at JRC Ispra - Other courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Place</th>
<th>Week</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>Advanced NDA for IAEA</td>
<td>PERLA</td>
<td></td>
<td></td>
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<tr>
<td>Primary Inventory Verification Pu (IAEA+ EURATOM)</td>
<td>PERLA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Verification</td>
<td>Ispra site</td>
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### Instrument courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Place</th>
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<tbody>
<tr>
<td>Waste Drum Monitor</td>
<td>In field</td>
</tr>
<tr>
<td>U Mass in MTR Plates</td>
<td>In field</td>
</tr>
<tr>
<td>Sealing systems</td>
<td>In field</td>
</tr>
<tr>
<td>...</td>
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</tbody>
</table>

### Other JRC Training:
- Nuclear Security Training
- DA Methods
- Statistics
E. General scheme of a course:

Theoretical background:
- Explain the method and instruments.
- Explain the inspection aim with a precise question, e.g.:
  “Can you confirm that the enrichment of this item is 3.6% as declared by the operator?”
- Discuss the answers “Yes” and “No”.

Do many practicals
- With equipment as used by inspectors in the field
- Do the set-up of equipment before measurements (repeatedly)
- Do many measurements on the wide range of nuclear material samples

Ask test questions every day

Final test: Work alone, verify a declaration, decide “Yes” or “No”.
Example of course contents for:

U enrichment determination by gamma spectrometry

1. General
   Interaction of gamma radiation with matter and gamma spectrum
   Types of detectors (Ge, NaI, LABR₃, CZT): principle, structure and performance
   Signal chain electronics: preamplifier, amplifier and MCA-166
   Physical, nuclear and chemical properties of Uranium
   Introduction to the uranium cycle
     - uranium ore dressing and concentrate production
     - uranium purification, conversion into UF₆ and fuel element preparation
     - reprocessing of irradiated fuel

2. Enrichment determination: techniques and software
   - method with *intrinsic calibration*: MGAU, principle, and field of application
   - methods *making use of standards*:
     - enrichment meter principle, infinite thickness
     - measurement with a Ge detector and UF₆ code
     - measurement with a NaI detector and U₂₃⁵ code
     - measurement with a NaI detector and NaIGEM code
... U gamma ... (cont.)

3. Practicals:

P 0: Electronics
P 1: Set-up of the gamma spectrometry chain
P 2: Energy calibration and resolution determination
P 3: Enrichment determination with NaI detector (with two calibration standards)
P 4: Enrichment determination with Ge coaxial detector (with calibration)
P 5: Enrichment determination with NaI detector (with one calibration standard)
P 6: Enrichment determination with Ge planar detector and without calibration
P 7: Measurement of the PERLA standard series

4. Nuclear material:

The samples used are reference samples of the PERLA laboratory:

Matrix: UO₂ and U₃O₈ powder, U alloy
Shape: pellets, pins, MTR plates, MTR assemblies, cylinder
Enrichment: from 0.31% to 92.4%
... U gamma ... (cont.)

5. Lecture notes:

Manual on Uranium enrichment verification by gamma-ray spectroscopy

Handbook of gamma spectrometry methods for non-destructive assay of nuclear materials (including measurement procedures),
- updated every 2 years
- hardcopy for course participants,
- electronic version on CD
- internet download from:

Course structure U enrichment

Handbook of Gamma Spectrometry methods for Non-destructive Assay of Nuclear Materials
P. Mortreau, R. Berndt
EUR 19822 EN, Joint Research Centre, Ispra

First published April 2001
Fourth revision June 2011
Electronic version by P. Mortreau, R. Berndt
F. Experience: What is important for training courses?

Work in a laboratory with "nuclear" atmosphere.

Give trainees real nuclear material in the hand. They need to touch it and to get acquainted with it, they need not to be afraid.

2 beginners per instrument,
1 experienced trainee per instrument
Trainees profit from

- time to work slowly step by step, but without help
- time to make errors and to correct them
- time to repeat measurements and to make own tests
- provoke wrong actions - to learn from mistakes
- limitation of the amount of contents to what they can understand in the limited time
Experience with training types

Trainers

1 trainer for 2 instruments (max. 4 trainees)

experienced trainers should answer any questions
hardware, software, electronics, detectors,
measurement errors,
fuel cycle, diversion scenarios,
radiation protection

Tests

small questionnaires every day, including very simple questions
G: Efficiency

Advantage of 1 week courses: Allows to cover a field systematically and in detail.

Disadvantage: The course does not meet exactly the interest of the participants – partially a waste of time and resources.

Alternative: Hold a small “training module”
Pilot course in August 2011:  
Training module on enrichment measurement with MGAU

<table>
<thead>
<tr>
<th><strong>Place:</strong></th>
<th>DG ENERGY, Luxembourg, gamma laboratory</th>
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</thead>
<tbody>
<tr>
<td><strong>Equipment:</strong></td>
<td>2 HRGe detectors plus spectrometer</td>
</tr>
<tr>
<td><strong>Nuclear material:</strong></td>
<td>CBNM LEU samples</td>
</tr>
<tr>
<td><strong>Trainers:</strong></td>
<td>1 trainer from Ispra plus the laboratory head of DG ENER (P. Mortreau and I. Puttaert)</td>
</tr>
<tr>
<td><strong>Duration:</strong></td>
<td>1 day</td>
</tr>
<tr>
<td><strong>Method:</strong></td>
<td>MGAU</td>
</tr>
<tr>
<td><strong>Trainees:</strong></td>
<td>4 inspectors</td>
</tr>
</tbody>
</table>
Pilot course in August 2011:
Training module on enrichment measurement with MGAU

Important: Restrict the contents so that there is time for

- introduction to the 1 method
- setup of the chains, also repeatedly,
- individual discussions,
- several measurements,
- Final test: Make an inspector’s decision.

Experience: A good course format in this specific case.
In-field training on enrichment measurement on UF$_6$ drums

Do we find an operator to support the training?
Other training aspects:

E-learning

Remains an option in case there is no place for practical training. Can not replace own practical experience. Can not replace dialogues and discussions with experienced trainers.

Alternative:

On the job training – new inspectors work with experienced and are in parallel supported by trainers at home.

PC assistance for inspectors:

We want to have a thinking inspector.