Remote Safeguards Technical Trainings under COVID19 Pandemic Constraints

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ABSTRACT

The Nuclear Security Unit of the Department of Nuclear Security and safeguards of the Joint Research Centre of the European Commission is delivering on a regular basis technical trainings for EURATOM and IAEA inspectors. Under normal circumstances, we cover the following topics in courses with physical presence allowing hands-one exercises:

- Uranium and plutonium isotopic verifications with gamma-ray spectrometry,
- Passive neutron assay,
- JRC ultrasonic seals for underwater and dry storage,
- Laser Mapping for Containment Verification (LMCV),
- 3D laser based verification system,
- Design Information Verification (DIV)(Basic Technical Characteristics (BTC) verification of Encapsulation Plants and Geological Repositories (EPGR),
- Tank calibration.

The programs of these specialized trainings include theoretical refreshers of the nuclear material subject to safeguards, hands on explanations related to instruments and material, practices of procedures and methods used by the inspectors, practical exercises and quizzes.

In 2020, while most of these trainings were cancelled due to the pandemic, three could still be organized. The first training took place in-person prior to the pandemic (early January 2020) whereas the two others were organized remotely in the second semester.

This paper will report, on one hand, about the first experience gained on remote trainings on both nuclear material isotopic (uranium enrichment and plutonium isotopic composition verifications) and DIV/BTC verification of EPGR and, on the other hand, about how the lessons learned in 2020 are examined/addressed for 2021 sessions. This paper is also meant to share best practices for online learning and show how important is the setting-up of the learning objectives of a remote learning with respect to in-person trainings.

1. INTRODUCTION

One of the missions of the joint Research Centre Directorate General of the European commission (EC JRC) is to provide technical and scientific support to other EC DGs, to EU Member States and to EU Development and Cooperation programs. EC JRC provides that support free of any possible conflict of interest that a research organization of a European Union member state (EU MS) may have. EC JRC is active in research and development fields, which fit the EU policy priorities. The Nuclear Security Unit (NUSEC) of the Department of Nuclear Security and Safeguards in the Directorate of Nuclear Security and Safety of JRC has a long experience in providing trainings to a large variety of customers and audiences in several fields such as nuclear safeguards, security including non-proliferation and export control of dual use commodities. An important part of the activities of the unit regards research and development on instruments and methods for nuclear material verification as well as trainings for EC DG ENER namely for EURATOM and IAEA inspectors [1-4]. These trainings include hands-on seals related courses, or other

containment and surveillance courses covering verifications as well as non-destructive assay techniques. The main delivered safeguards trainings are:

- Uranium and plutonium isotopic verifications with gamma-ray spectrometry,
- Passive neutron assay,
- JRC ultrasonic seals for underwater and dry storage,
- Laser Mapping for Containment Verification (LMCV),
- 3D laser based verification system,
- DIV/BTC verification of Encapsulation Plants and Geological Repositories (EPGR),
- Tank Calibration

These trainings covering key activities of nuclear safeguards are delivered in NUSEC laboratories such as PERLA, AS3ML (including SILAB, Tank calibration and 3D laboratory) in JRC Ispra. In fact, the NUSEC unit is delivering these training since almost four decades for EURATOM inspectors, which represents a very substantial contribution to the training programs of Nuclear Safeguards Inspectors of DG-ENER (Nuclear Safeguards inspectors Directorate, Luxembourg) and IAEA Nuclear Safeguards Department. Worth to be mentioned, NUSEC unit is also yearly organizing the international ESARDA Course (European Safeguards Research and Development Association) and organizes several out-reach safeguards and non-proliferation course [5-9] in Europe and the rest of the world.
The trainings for safeguards inspectors are held in Ispra in routine, up to two times per year for each of the safeguards subjects as well as on ad hoc demand.
This paper will report, on one hand, the first experience gained on remote trainings on both nuclear material isotopics (uranium enrichment and plutonium isotopic composition verifications) and DIV/BTC verification of EPGR and, on the other hand, how the lessons learned in 2020 are examined/addressed for 2021 sessions.

2. 2020 COVID19 PANDEMIC CONTEXT

In 2020 and before the pandemic (January to February) two safeguards hands-on trainings were successfully organized in PERLA. The first was on Neutron counting for EURATOM inspectors and the second on both gamma-ray spectrometry and neutron counting under a collaboration with the Japanese Atomic Energy Agency (JAEA) as outreach training for Asians and East European trainees. Most of the planned trainings were cancelled due the COVID19 waves. However, since the EURATOM inspections continued to occur in 2020 despite of the pandemic, special efforts for development of remote/on-line training were made. It's worth mentioning that these trainings, when organized in-person in JRC Ispra, include classrooms sessions and, most importantly, laboratory sessions with hands-on instruments and nuclear material. As mentioned above, two remote safeguards trainings were successfully organized under the pandemic restrictions to full fill the EURATOM needs. The virtual nature of these two trainings required some adjustments with respect to the traditional course delivered in presence in Ispra. The original substantial content offer with combinations of lectures was conserved, together with group exercises and quizzes.

3. THE FIRST EXPERIENCE ON A REMOTE TRAINING FOR DESIGN INFORMATION VERIFICATION (DIV) ACTIVITY DURING THE PANDEMIC

A remote training session focused on preparing the DIV activity in Onkalo (Finland) was organized making use of Webex on 29 September, 2020 with participants from JRC in Ispra, ENER in Luxembourg, and IAEA (SGTS and SGOC4) in Vienna. In total 5 participants from IAEA and 4 Euratom Inspectors have attended the course. The training was an opportunity to review the work plan, practice the usage of both 3DLR and MLSP systems and rehearse the post processing using STEAM software.
The course was delivered, as a hybrid course constituted of:

- Presentations, videos on how to operate the system and on how to use the post processing software,
- Hands-on training on the system and software

In order to achieve the 2nd bullet point (hands on) the IAEA participants in Vienna were sitting together in a meeting room, have a replica of the system and could exercise with it while have guidance from the JRC in Ispra. The same for the processing software all participants could follow the processing live by following the share screen from the lecturers in Ispra. The topics of the training course included:

- **Static Scan Acquisition**
  - Operation of 3D scanner (including update for new ZF 5016 instrument),
  - Procedures for scan planning and acquisition,
- **3D Scan Processing**
  - Data signing and authentication,
  - Import and processing of new scans (including registration in STeAM Desktop),
  - Import of new design information (CAD drawings),
  - Verification of design information,
  - Change analysis for validation of mobile scanner,
  - Data backup,
- **Mobile Scanning**
  - Data preparation (pre-processing of reference map),
- **Operation of Mobile Scanner**

The hybrid format of the course turn on to be very successful. The feedback was very good. The overall points were 5 (out of 5) for IAEA and 9 for ENER (out of 10) with a very positive comment “Very useful and good course and practical on hand training”.

4. THE FIRST EXPERIENCE ON A REMOTE TRAINING ON URANIUM ENRICHMENT AND PLUTONIUM ISOTOPIC COMPOSITION VERIFICATIONS

The training started with an opening ceremony with an address of the management of JRC NUSEC unit and a tour de table where the trainees introduced themselves. The learning objectives were indicated and repeatedat different stages all along the training period.
This remote training on uranium enrichment and plutonium isotopic verifications used Microsoft Teams Platform and its available applications such as Microsoft STREAM. The training was designed for six EURATOM trainees. It included five theoretical live presentations (through PowerPoint slides and digital whiteboard for deep explanations and clarification on the contents) and nine virtual lab sessions (through videos), which aimed to be very interactive. The training was broadcasted from JRC Ispra site and took place from November 27th to December 2nd with the weekend excluded. The schedule of the course is shown in Table 1.
The course presented an initial challenge for some of the trainees regarding the communication tools (Microsoft Teams and Stream). Therefore, several connectivity tests were organized individually and collectively with the trainees. The training required intensive efforts for the organizers to best fit the leaning objectives and to be as close as possible to those trainings organized in-person. The recording of videos of the lab sessions constituted the major part of the preparation of the training. Recordings of the videos was very time demanding considering that all was done in a radiation controlled area using nuclear material also with limited staff due to the covid restrictions. In fact, only limited staff could

access the JRC Ispra site and PERLA lab where all the videos of the training were taken. Figure 1 shows a large view of the entrance of PERLA lab. Each of the nine videos required often several recordings to enable a delivery of a minimum required video quality and structure. The recorded videos and lectures were put available beforehand to the trainees, covering standard operations for the analysis methods of nuclear material (uranium enrichment and plutonium isotopic composition determination), operating the gamma-ray detectors and their electronic acquisition chains and running the different software and calculation codes needed for uranium enrichment and plutonium isotopic composition determinations.

Figure 1: A large view of PERLA lab in JRC Ispra (Italy)

4.1 Structure and content of the training

Regarding the NDA safeguards training delivered in-person meaning those using gamma-ray spectrometry or neutron counting, a full training week is dedicated for each of the topics such as verifications of uranium enrichment, plutonium isotopic composition or nuclear material mass. However in the case of this first experience on remote NDA training, uranium enrichment and plutonium isotopic composition verifications were merged to fill in three and half day considering that all preparation work with and without the trainees was preformed beforehand. The main pillars of the training are:

- Introduction of the course and the participants,
- Short rational of nuclear safeguards,
- Overview of radiation physics
- NDA techniques and methods,
- Introduction of gamma-ray spectrometry and their acquisition system,
- Gamma-ray detectors used in Safeguards (HPGe, NaI (HM5), CZT, LaBr3 …),
- Theory and hands-on uranium enrichment determination,
- Theory and hand-on plutonium isotopic composition determination,
- Quiz and training feedback gathering.

4.2 Live lectures of the training

The lectures were given live via Power Point presentations. The audience is constantly invited to interact with the trainers. In order to enhance effectiveness and efficiency of the lectures, in addition to lecture slides, some equipment and instruments used in the virtual lab sessions, which are in fact those that are used by EURATOM and IAEA inspectors are also shown live during lectures. All the lectures were shared beforehand with the trainees. The Teams Group of the training was created few weeks before to ensure that all the trainees got used to Teams software and its apps. The Teams group is left accessible after the training. Some of the sessions of the training are recorded for the archives. Figure 2

shows pictures of the control room of the training and the area in PERLA were most of the videos of the lab sessions were recorded. Figure 3 shows examples of equipment and software live demonstrations during live lectures. Figure 4 shows examples of live demonstration of gamma-ray spectrum of a plutonium sample with a High purity germanium detector (left) and uranium sample with a HM5 handheld detector. The duration of a lecture often averaged 90 minutes durations as it included intensive interactions between the trainers and trainees.

Table 1: Overview of the first virtual training course on uranium enrichment and plutonium isotopic composition held under the COVID19 pandemic context (2020)

Day 1, Friday, Nov 27th 2020	
09:30-10:00	**Opening Ceremony:** ➢ **Addresses** ✓ Stefan Nonneman, Head of Unit, JRC GII7 ✓ Kamel Abbas, Project Leader and Trainer, JRC GII7 ➢ **Tour de table** ➢ **Presentation of the training**
10:00-12:00	**Lecture 1:** Overview of NDA Techniques for Nuclear Material Verifications **Lecture 2:** Basics of Radiation Physics for NDA of Nuclear Material **Discussions**
12:00-14:00	*Break*
14:00-17:00	**Lecture 3:** Introduction of Gamma-ray Spectrometry, Electronics Instrumentation and Signal Processing used for U and Pu isotopic verifications **Hybrid Lab Session 1 (20 min Video + live interactions):** Short Introduction of Health Physics and Practical Behaviour in Radiation Controlled Areas. **Discussions**

Day 2, Monday Nov. 30th 2020	
09:00-12:00	**Hybrid Lab Session 2 (43 min Video + live interactions):** Presentation of the main Gamma-ray Detectors used for U enrichment and Pu Isotopic composition verifications including the electronic chain (MCA 527) and "WinSpec-for-Inspectors" software **Hybrid Lab Session 3 (55 min Video + live interactions):** Setting-up and Calibration of a HPGe detector with MCA 527 and WinSpec **Hybrid Lab Session 4 (40 min Video + live interactions):** Setting-up of a CdZnTe detector with MCA 527 and WinSpec
12:00-14:00	*Break*
14:00-17:00	**Hybrid Lab Session 5 (40 min Video + live interactions):** Setting-up of a NaI detector (scintillator) **Lecture 4:** Verification of U Enrichment **Hybrid Lab Session 6 (46 min Video + live interactions):** Verification of U enrichment with a HPGe detector and MGAU Code

Day 3, Tuesday, Dec 1st 2020	
09:00-12:00	**Hybrid Lab Session 7 (35 min Video + live interactions):** Verification of U enrichment with a NaI scintillator and NaIGEM Code **Hybrid Lab Session 8 (29 min Video + live interactions):** Verification of U enrichment with HM5 **Lecture 5:** Verification of Pu Isotopic Composition
12:00-14:00	*Break*
14:00-16:00	**Hybrid Lab Session 9 (24 min Video + live interactions):** Verification of Pu Isotopic Composition with a Planar HPGe detector and MGA Code

Day 4, Wednesday, Dec 2nd 2020	
09:00-12:00	- Quiz - Summary of the training, - Evaluation of the training by the trainees - Closing addresses

Figure 2 shows pictures of the control room of the training (on the left)) and the area in PERLA were most of the videos of the lab sessions were recorded (on the right)

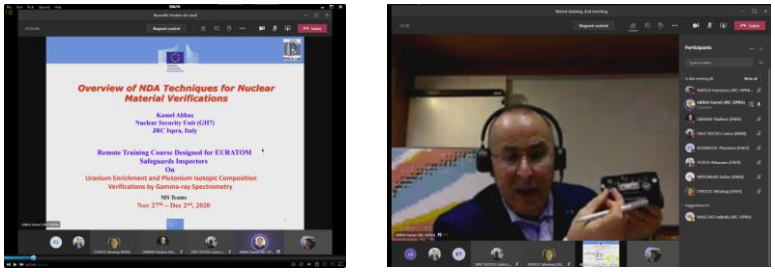


Figure 3: Examples of presentations during live lectures of equipment and software used for uranium and plutonium isotopic composition verification. On the left, an example of a first slide of a lecture as seen by the remote audience and on the right the MCA 527 module held by the trainer. MCA527 (manufactured by GBS Electronik (Germany)) is an an important component of gamma-ray spectrometers of safeguards inspectors.

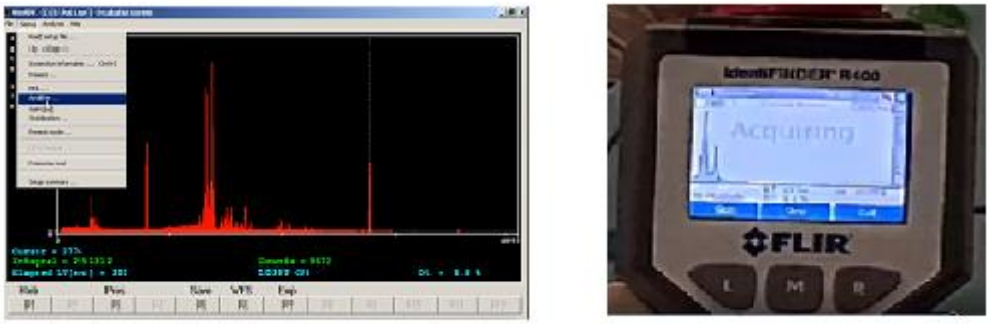


Figure 4: Examples of presentations during live lectures of equipment and software used for uranium and plutonium isotopic composition verifications such as gamma-ray spectrum acquisition of a plutonium sample with a High purity germanium detector (left) and uranium sample with a HM5 handheld detector

4.3 Lab-sessions (hybrid lab session)

A lab session of this first experience on an on-line technical training for safeguards inspectors consisted of viewing recorded videos of uranium and plutonium isotopic composition verifications using validated equipment, tools, software and calculation codes as well as real nuclear material as in training in-person in PERLA laboratory. Handling and transferring video files can be time consuming depending on the performance of the local connectivity. All the videos of the lab sessions were uploaded in Microsoft STREAM platform to allow trainees to view them at their convenience prior to the dedicated time slots. The videos were viewed freely by the trainees via their computers of smartphones as one does with YouTube media. During the time slots of a lab session, they invited to view it again in the spirit to draw a list of questions/comments/suggestion to be discussed during at the end of the session. Most of the audience attended the training from their private home due to the pandemic lockdown.

As anticipated above, the preparation and recording of the videos (MP4 file format) required majority of the preparation time of the training. Figure 5 shows a screenshot of prepared videos with indications on the topics.

Instructing uranium enrichment with HM5 instrument

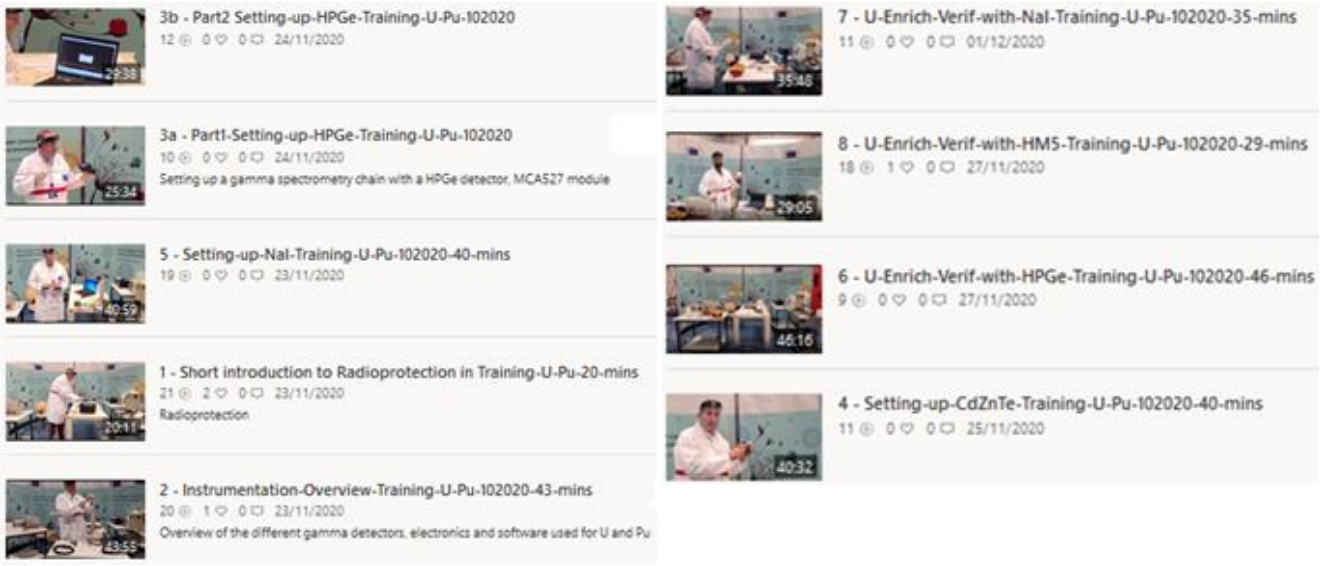


Figure 5: Overview of the topics of the nine videos prepared for the lab sessions of the training

4.4 Quiz, trainee feedbacks

The last session of the training started with a quiz in which the questions were based on the learning objective of all the sessions of the training. The results were provided, openly discussed, with comments and suggestions between trainees and trainers in order to maximize the effectivity of the training. The overall result of the quiz was similar to the one obtained during the course with in-person presence.

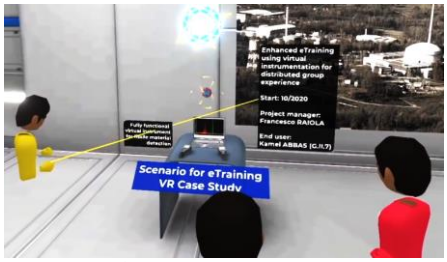
As a first experience of this on-line technical training, the feedback from the trainees was very much expected. The training organizers gathered those feedbacks just after the quiz time slot. The distributed feedback forms consisted of about 40 questions, some with multiple-choice answers. The questions were about the substance and quality of the organization of the lectures, lab sessions and the standard operation procedures including

ranking the trainer efficiencies. Their feedbacks included comments and suggestions on how to make on-line trainings as efficient and effective as trainings in-person.
All the participants showed a great appreciation of the general organization of the training although some of the trainees repeated their remarks on the importance of hands-on instruments familiarization, which was not possible to plan due to the pandemic restrictions. This point triggered a long discussion and debate on the digitalization of safeguards in general pointing out the impact of social contacts and maters.

5. CONCLUSION, LESSONS LEARNED AND WAY FORWARD.

The major part of the technical safeguards trainings such as those delivered by JRC NUSEC unit to EURATOM inspectors is hands-on making use of instruments as used in real inspections, practicing various analysis techniques and methods, which are validated for nuclear safeguards and therefore used by IAEA, EURATOM and other national and regional safeguard authorities. It is going without saying that these trainings are prerequisites for inspectors duties. They are needed for young inspectors but not only, training refreshments are also need for experimented inspectors to learn about new development and novelties in the field and also to report their feedbacks to the trainers to anticipate future needs or tailor and plan updated trainings when needed.
The important lesson learned in this first experience of on-line technical safeguards trainings presented in this paper is that many sessions of the program of such trainings can be successfully and efficiently organized on-line regardless the situation of a pandemic. In fact, ‘’thanks’’ to the pandemic, state-of-the-art communication platform, hardware and software were made available, explored and successfully tested since the beginning of the pandemic. These tools were successfully used mainly for teaching the more theoretical topics and exercises. Trainees emphasized the importance of hands-on training making use of real instruments, what is not straightforward to be done on-line. JRC Ispra is experimenting with remote control of inspector equipment in two directions. Trainees could remotely access experimental setups in JRC ISPRA, but reversely trainers could remotely connect to setups in the labs of the inspectorates. Additionally, JRC Ispra has developed emulators generating signals collected by measuring reference nuclear material samples. These emulators substitute the needed nuclear materials and allow using classical measurements chains.
After the pandemic crisis and having invested in on-line based training solutions, all the material is available to allow trainees to prepare themselves for Q/A sessions with the trainer about the more explanatory and theoretical parts of the course without needing to travel and at their own pace. In a first instance, the hands-on part will be organized with physical presence during a period of two to three days, allowing also testing the knowledge of the trainees. At a later instance, also the hands-on part of the training will be organized remotely but will require the presence of the trainer. In case the situation of the pandemic returns to normal, these trainings will return at least partially to in-person mode, (sort of hybrid trainings, as presented in this paper, the way forward is the investigation of innovative ideas for the on-line ‘’hands-on’’). This will be a significant evolution of on-line safeguards technical trainings, which contributes for enhancing our resilience. The availability of remotely accessible and controlled equipment for training purposes brings training activities much closer to support of inspectors during inspections where the same remotely controllable equipment would allow support during crisis periods. Additionally, it is expected that the new visualization/communication technologies based on virtual or added realities to play a major role for smart and remote working including training (see Figure 6), which would reduce the ecological fingerprint of safeguards inspections and in this way contribute to achieve the objectives of the Green Deal.

A virtual lab visit in PERLA lab showing various intruments. Two neutron detectors used for training for mass determination are visible in orange color.



A virtual training session on gamma-ray spectromtery for nuclear materail analysis. Two identifienders ; the so-called HM5 in safegurds are visible in a frond of the laptop dipalying a gamma-ray spetrum.

ND Hub; a virtual reality platform for e-learning and e-working in nuclear decommissioning and waste management that can be used also for safeguards training.

Figure 6: Examples of applications of virtual and augmented realities of interest for on-line safeguards technical trainings

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ACKNOWLEDGMENTS

The co-authors would like to thank indeed the colleagues of both EC JRC Nuclear decommissioning Security and Nuclear Security Units for their support and commitment to make this first experience of on-line safeguards technical to happen successfully training ESARDA Course to happen successfully.