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Responding to Evolving Safeguards Challenges at Fukushima Dai-ichi

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Abstract

The IAEA Department of Safeguards relies heavily on the timely access of inspectors to nuclear material and facilities to support the drawing of conclusions. The conditions on the Fukushima Dai-ichi site after the impact of the 2011 Great Tohoku Earthquake and tsunami posed unprecedented and continuously evolving challenges. To overcome these dynamic challenges, the IAEA has developed innovative measures that support the IAEA's mission of drawing independent conclusions, and worked in close cooperation with the Japan Safeguards Office (JSGO) of the Japan Nuclear Regulation Authority and with the Tokyo Electric Power Company (TEPCO) to implement the measures on the site, to provide assurance of the non-diversion of nuclear material to non-peaceful activities. These innovations have been a combination of technological advances and adaptations of the safeguards approach to the site; the implementation also takes benefit of enhanced cooperation provided by JSGO and TEPCO.

The IAEA has developed and installed technologies on the site that, in the event of undeclared removal of spent fuel from the damaged units, would be capable of detecting it. Additionally, the IAEA developed new technologies and techniques to verify the fuel recovered from the spent fuel ponds of the damaged units, some of which is rubble-encrusted, distorted or bent. The IAEA has worked to return a number of facilities to a routine verification regime despite the difficult conditions, has regularly accessed the site to perform design information verification activities as decommissioning work has opened new possibilities for access, and has implemented regimes of short-notice access to build confidence in the absence of undeclared activities at the site in the wider context of the State-level approach for Japan.

Benefitting from these responsive innovations, and through enhanced access to the site with the cooperation of JSGO and TEPCO, IAEA safeguards at the site has successfully continued after the tsunami, and will continue to evolve as the conditions on the site change over time.

The Impact of the Fukushima Dai-ichi Accident on IAEA Safeguards on the Site

The Accident

On 11 March 2011, the Great Tohoku Earthquake, with a magnitude of 9.0 M_W, struck a broad area of northern Japan. The earthquake and subsequent tsunami caused extensive physical damage on the Fukushima Dai-ichi Nuclear Power Station site, operated by Tokyo Electric Power Company (TEPCO). The facilities on the site included six boiling-water reactors (BWRs) and two associated spent fuel storage facilities — a large spent fuel storage pond facility (the common spent fuel storage facility, CSFS), and a smaller dry storage cask installation (the cask custody building, CCB). Reactor Units 1, 2 and 3 suffered major damage, including partial core melting, due to loss of cooling caused by a total power failure. Unit 4 was undergoing maintenance, and the core was empty, however the reactor building was damaged by an explosion. Units 5 and 6, which were also under maintenance, and the CSFS and CCB suffered only minor damage.

IAEA Safeguards on the Site at the time of the Accident

The six BWRs and the two storage facilities contained nuclear material under IAEA safeguards, with a large quantity of irradiated fuel in the form of spent fuel assemblies, and a much smaller quantity of fresh low-enriched uranium fuel (fresh fuel assemblies). The number of fresh and spent fuel assemblies at each facility at the time of the accident were as follows:

- **Unit 1** held 400 fuel assemblies in the operating core, and 292 spent fuel assemblies and 100 fresh fuel assemblies in the spent fuel pond.
- **Unit 2** held 548 fuel assemblies in the operating core, and 587 spent fuel assemblies and 28 fresh fuel assemblies in the spent fuel pond.
- **Unit 3** held 548 fuel assemblies in the operating core, and 514 spent fuel assemblies and 52 fresh fuel assemblies in the spent fuel pond[1].
- **Unit 4** was in an outage, with all core fuel (548 assemblies) unloaded to the spent fuel pond, which also contained 783 spent fuel assemblies and 204 fresh fuel assemblies.
- **Unit 5** was in an outage, with the core loaded with 548 fuel assemblies but with the missile shield removed. There were 946 spent fuel assemblies and 48 fresh fuel assemblies in the spent fuel pond.
- **Unit 6** was in an outage, with the core loaded with 764 fuel assemblies and the missile shield in place awaiting reactor restart. There were 876 spent fuel assemblies and 64 stored fresh fuel assemblies in the spent fuel pond.
- **Common Spent Fuel Storage Facility (CSFS)** held 6375 spent fuel assemblies in the spent fuel pond.
- **Cask Custody Building (CCB)** contained nine dry storage casks, holding 408 spent fuel assemblies that had been transferred from Unit 4 and Unit 6.

In total, the nuclear material inventory on the site was 14 633 fuel assemblies, of which 2 808 were loaded into the reactor cores, 11 329 were spent fuel stored in the spent fuel ponds or dry casks, and 496 were unirradiated fresh fuel assemblies.

This material was safeguarded by the IAEA using a regime consisting of yearly physical inventory verification (PIV) inspections at each facility, coupled with interim inventory inspections conducted on a randomised basis (random interim inspections, RIIs). The inspections were supplemented by design information verification (DIV) visits, and the site as a whole was subject to the complementary access (CA) provision of the Additional Protocol. As such, there was reliance on the timely access of inspectors to nuclear material and facilities to perform the inspections. Other measures that could be performed remotely were also available to the IAEA, such as satellite imagery analysis and the monitoring of open source information.

Immediately following the accident, no access by IAEA safeguards inspectors was possible due to the severe radiological conditions on the site and damage to site infrastructure. Furthermore, as the IAEA surveillance cameras were rendered inoperable due to lack of power and the IAEA seals on the operating reactors cores could not be accessed, the IAEA lost the *continuity of knowledge* on the nuclear material on the site that had been maintained since the previous inspections.

IAEA Safeguards response immediately following the Accident

With access to the site and nuclear materials not possible, the situation posed an unprecedented challenge to IAEA safeguards, as this was the only major nuclear accident that had occurred on a site under full-scale safeguards[2]. However, the IAEA safeguards system was able to respond, as it includes provision for a situation — known as an *Anomaly* — where an unusual condition restricts the ability of the IAEA to draw conclusions on the non-diversion of nuclear materials at a facility. A methodology is provided for the handling, reporting and eventual resolution of an anomaly, which can be achieved through reverification of the nuclear material involved. Given the restrictions to access by inspectors, anomalies were opened for each facility on the site.

With the anomalies opened, the IAEA developed an action plan with compensatory measures to provide coverage of identified potential diversion scenarios. The safeguards measures undertaken across the State were adjusted, with additional CA, DIV and routine inspection activities performed. Additionally, the plan ensured that safeguards for Fukushima Dai-ichi did not stop, as other measures such as satellite imagery analysis and monitoring of open source information were employed to provide information on the situation on the site that helped bridge the knowledge gap before inspectors were again able to gain access.

The first post-accident access to the site by a team of IAEA safeguards inspectors was in October 2011. The team carried out inspections in the least damaged facilities on the site, namely Units 5 and 6, and the two spent fuel storage facilities (CSFS and CCB). IAEA surveillance systems in those facilities were removed and replaced with new systems, and seals were replaced and verified where possible. However, the conditions in the facilities were such that the fuel assemblies stored in the spent fuel ponds could not be reverified, and the fuel assemblies in the loaded cores at Units 5 and 6 could not be accessed. The nuclear material left unverified was placed under surveillance for future verification.

The inspectors witnessed the extent of the damage on the site and, through measurements of the radiation levels at various locations, confirmed the reason for restricted access to areas of the site, including the heavily damaged Units 1–4.

The team were able to re-establish a routine inspection regime in Units 5 and 6, and the CSFS and CCB, which has been maintained since.

Post-Accident Safeguards Approach for the Fukushima Dai-ichi Site

Approach to reverification of Nuclear Material on the Site

Having established the situation on the site through the October 2011 inspection, the IAEA developed a safeguards approach for the site in consultation with the Japan Safeguards Office (JSGO) of the Japan Nuclear Regulation Authority. This approach contains a strategy for reverification of the nuclear material on the site, coupled with measures to provide assurance of non-diversion of the nuclear material to non-peaceful activities. The reverification strategy is based on categorising the material on the site into three groups:

1. Fuel assembles in the accessible facilities (Units 5 & 6, CSFS, CCB);
2. Fuel assemblies in the spent fuel ponds of the inaccessible damaged reactors (Units 1–4); and

3. Damaged fuel assemblies (melted fuel debris) in the reactor cores of Units 1, 2 and 3.

Category 1 — For the fuel assemblies in the accessible facilities, which make up about 70% of the total number of fuel assemblies on the site, the IAEA approach is to keep containment and surveillance measures on the assemblies and reverify as soon as the facility conditions allow.

Category 2 — The spent fuel ponds of the damaged reactors contained about 20% of the total number of fuel assemblies on the site. The IAEA approach for this material is to reverify the assemblies as they are made available through the TEPCO decommissioning operations, while addressing identified diversion scenarios through optical and radiation surveillance measures coupled with frequent short-notice on-site activities by inspectors. This has required the development of innovative technological and access measures, which are described below.

Category 3 — The inaccessible material in the damaged reactor cores contains nuclear material in the form of partially melted core fuel debris of a quantity that is equivalent to about 10% of the total number of assemblies on the site. This material is currently the focus of study at the IAEA as it represents a new material type that is neither completely representative of spent fuel in item form or waste. The IAEA approach for this material is to maintain confidence that the nuclear material in the core fuel debris remains in the damaged reactor cores, and to safeguard the material as it is retrieved. This approach requires a combination of measures including information analysis and verification, short-notice activities by inspectors, and satellite imagery analysis and monitoring of open source information to assess and confirmed the status of the retrieval projects.

Other Safeguards Activities on the Site

The objective of the Safeguards Approach is to bring all the nuclear material on the site back under safeguards, resolve the anomalies at the facility, and to reinstate the regime of PIV and RII inspections at the facilities on the site. As such, the approach contains the details of activities that are performed on the site during the PIV and RII inspections. In addition, the approach includes provision to support the spent fuel management activities performed by TEPCO on the site, in particular the transfer of spent fuel assemblies to dry storage casks.

Enhanced cooperation with the State

Given the inaccessible material on the site and the complex nature of the post-accident decommissioning operations, it was recognised by all parties that a high level of cooperation was required in order to implement the safeguards approach on the site. To that end, JSGO has worked with TEPCO to facilitate enhanced cooperation with the IAEA, including the provision of regular advance information regarding the on-site operations, and responses to ad hoc requests for equipment installation and access from the IAEA. This has led to specific measures being implemented on the site, as discussed later in this paper. TEPCO also provides supplementary information to the IAEA, for example the results of their investigations into the condition of the damaged reactors, including dose rates surveys and video images from remotely operated vehicles.

The enhanced cooperation was formalised in 2012 with the establishment of the Fukushima Task Force, which includes members from the IAEA and JSGO, the site operator TEPCO, and relevant Japan technical organisations. Sub-groups have been created within the Task Force that provide working level forums for information sharing and discussion on different aspects of safeguards on the site — for example, the Damaged Cores Sub-Group that focusses on the safeguards issues surrounding the fuel debris material in the damaged reactor cores.

In addition, Japan has provided a cost-free Expert (CFE) to the IAEA, specifically to provide support to the Task Force and sub-groups, and to work on issues related to safeguards at the site.

Implementation of the Post-Accident Safeguards Approach

The IAEA began implementing the post-accident safeguards approach in 2012. The progress of reverification of the nuclear material has necessarily followed the decommissioning activities managed by TEPCO on the site. Significant progress has been made, which has allowed, at the time of writing, all the nuclear material in the accessible facilities (category 1), and approximately half the undamaged assemblies in the inaccessible facilities (category 2) to be reverified. The remaining unverified material is in the spent fuel ponds of Units 1 and 2, and in the damaged cores of Units 1, 2 and 3.

Reverification of Category 1 material: Fuel Assemblies in the Accessible Facilities

For the fuel assemblies in the accessible facilities (Units 5 & 6, CSFS, CCB), the containment and surveillance measures (surveillance cameras, and seals on reactor cores and dry casks) had been re-established during the first post-accident inspection in October 2011. These measures were maintained during the period before reverification was able to be performed; this was achieved in the subsequent years, once the cranes and fuel handling machines in the facilities became available. With reverification of these items, which make up about 70% of the total number of fuel assemblies on the site, all nuclear material in category 1 was brought back under safeguards within four years following the accident and the anomalies at Units 5 & 6, CSFS and the CCB resolved. A regime of routine PIV and RII inspections has been reinstated at these facilities.

Reverification of Category 2 material: undamaged fuel assemblies from Units 1 – 4

The accident left large numbers of spent fuel assemblies in the spent fuel ponds of the four damaged reactors, with no working infrastructure to remove them. The policy developed by TEPCO for recovery of these assemblies is to design and install new infrastructure (covers for Units 1, 3 and 4, and an access gantry for Unit 2) that incorporate fuel handling equipment for loading assemblies into a spent fuel cask[3]. The cask is then used to transfer the assemblies to the CSFS for storage in the spent fuel pond. To date, the covers have been completed at Unit 4 (in 2014), and Unit 3 (in 2019), with the construction of the Unit 2 access gantry and the Unit 1 cover ongoing.

Reverification of undamaged fuel assemblies from Units 3 & 4

In November 2013, the transfers from the spent fuel pond of Unit 4 to the CSFS started, with the first cask containing 22 fresh fuel assemblies. Regular cask transfers of spent fuel commenced thereafter. Prior to these transfers, the IAEA installed XCAM surveillance cameras in Unit 4 to monitor the removal of casks. The receipt of casks, and the subsequent unloading of fuel and storage in the spent fuel pond was monitored by XCAMs installed in the CSFS. The received assemblies could then be verified by the IAEA. The fuel assembly transfer campaign continued throughout 2014 and, by the end of that year, all assemblies had been removed from Unit 4, and successfully reverified by the IAEA, allowing the anomaly on Unit 4 to be resolved.

The same process was repeated with the transfers from Unit 3, which commenced in April 2019, and were completed in February 2021. With the reverification of this nuclear material[4], the total number of fuel assemblies reverified has reached over 80% of the total number of assemblies on the site at the time of the accident.

Challenges in reverifying the recovered material from Units 3 & 4

During the reverification of the transferred assemblies, it was found that the verifications activities normally undertaken by the IAEA at reactors in Japan are not always possible, due to deformation and/or deterioration of some of the recovered assemblies. In these cases, alternative verification activities have been performed that are considered to give equivalent results.

For example, the reverification of the spent fuel assemblies in the spent fuel pond is normally performed using an ICVD[5]. However, during reverification of the spent fuel assemblies received from Unit 3, it was found that the Cherenkov light of some assemblies was not visible, due to obstruction by rubble and deposits. Instead, a two-stage approach was taken, in which the entire population of assemblies were first verified using a new IAEA SG verification device, the XCVD[6], which also served to identify those assemblies with obstructed Cherenkov light and to keep record of the measurement. The identified fuel assemblies were then treated as a separate population (sub-stratified), and verified using an IRAT detector[7].

This was the first time that the XCVD has been used to verify nuclear material, and the challenge of reverifying the recovered fuel drove the final development and authorisation of the instrument for use at the site, and later throughout Japan. The XCVD is expected to become a standard device used worldwide for IAEA Safeguards verification.

Another challenge occurred during reverification in the spent fuel pond of fresh fuel assemblies received from Unit 3. It was found that the serial number of some assemblies had been obscured by fixed deposits, preventing identification even when using an underwater camera[8]. As identification was not possible, this population of fresh fuel assemblies were measured using a modification to a standard IRAT detector assembly, which enabled the presence of ^{235}U in the target assembly to be determined. The use of this new instrument — the Fresh Fuel Attribute Test (FFAT) detector — was the first time that verification of fresh fuel by underwater NDA had been performed in Japan.

Future Reverification of undamaged fuel assemblies from Units 1 & 2

Preparations are being made on the site for the removal of undamaged fuel assemblies for Units 1 and 2, with the installation of the cover for Unit 1 and the access gantry for Unit 2. Once completed, the fuel assemblies will be transferred to the CSFS. These transfers are scheduled to start in FY2024–FY2026 from Unit 2, and FY2027–FY2028 from Unit 1. The IAEA will verify the fuel assemblies on receipt in CSFS in the same way as the transfers from Units 3 and 4. The condition of the recovered fuel assemblies, particularly those from Unit 1, where rubble from the explosion fell into the spent fuel pond, may pose new challenges during reverification, and the IAEA will continue to develop new instrumentation and techniques to meet any future challenges.

Future Reverification of Category 3 material: Fuel debris in the damaged cores of Units 1 – 3

Fuel Debris Retrieval

Future plans are being developed for the retrieval of the fuel debris from Units 1, 2 and 3. The retrieval of fuel debris is an unprecedented technical challenge, and extensive R&D activities have been and continue to be performed by the State of Japan. These activities are monitored by the IAEA through review of the declarations made under the Additional Protocol, and through open source analysis, with complementary access (CA) visits under Article 5 made to confirm the declarations when considered necessary. For example, the IAEA has conducted CAs to locations at which robotic devices related to fuel debris retrieval are being developed.

Retrieval operations will start in Unit 2, as this unit suffered the least structural damage and has the lowest dose rate conditions. It is planned to access and extract fuel debris material from the region below the core, using robotic arms that will be mounted in an enclosure installed on the ground floor of Unit 2. A staged approach to retrieval is planned, starting with small-scale sampling scheduled to occur around 2022, with the scale of retrieval increasing at each subsequent stage.

In October 2020, a design information verification (DIV) visit was made to the location in Unit 2 where the enclosure through which the samples will be retrieved will be installed. This visit highlighted the difficulties in performing inspection activities in that area, due to the high radiation levels and potential for contamination. These factors will be taken in account during the development of the approach for safeguarding the retrieval of material.

The next retrieval stage will occur once new facilities have been built on the site to handle and store the retrieved fuel debris. Two new facilities are planned for the site: a temporary storage facility, which will receive and store the fuel debris material from Unit 2; and a hot-cell laboratory facility that will be used to analyse samples. The safeguards approach for these facilities is under development. As part of this development, the IAEA is working closely with JSGO and TEPCO to consider how best to characterize the removed fuel debris, account for its nuclear material contents and apply safeguards measures to the planned removal and storage processes.

Further stages will see the retrieval of larger quantities of fuel debris from Unit 2 and, in the longer term, from Units 1 and 3. The IAEA safeguards approach for these future retrieval operations will be developed in the future, using the lessons learned from the early retrieval stages.

Confidence building SG measures

The decommissioning operations on the site are complex, with many unique challenges, and necessarily will require many years to complete. The IAEA Safeguards approach for the site recognises this, and in response incorporates measures designed to enable the IAEA to provide assurance of the non-diversion of nuclear material to non-peaceful activities indirectly, given the inaccessible nuclear material that cannot yet be verified. This has required the development of innovative technological and access measures, which are described here.

Outdoor cameras and Radiation Monitoring system

Given the damage to Units 1, 2 and 3, in particular the exposed nature of the spent fuel ponds at Unit 1 and Unit 3, the IAEA recognised that measures were required to safeguard against the diversion of spent fuel from these units directly (i.e. the use of the external cranes that have been installed around these units to lift fuel from the spent fuel ponds). To that end, outdoor XCAM surveillance cameras and a radiation monitoring system (the *Open-Air Spent Fuel Monitor, OASM)* have been installed on a hillside facing these units. The OASM is composed of two neutron slab detectors and two LaBr gamma detectors, and was purpose-designed and constructed by the IAEA to have the capability to detect the removal and transfer of an unshielded fuel assembly from the spent fuel ponds of Units 1, 2 and 3. The data from the XCAM cameras and OASM is collected and remotely transferred to the IAEA for review.

Cameras on removal routes

TEPCO has a continuous programme to install infrastructure at the damaged reactors in preparation for retrieval of the inaccessible nuclear material. To safeguard against the diversion of material using the improved infrastructure, the IAEA has systematically installed surveillance cameras on newly established removal routes in the damaged reactors. All cameras are serviced and reviewed periodically. The changes to the infrastructure at the damaged reactors are monitored by the IAEA, and additional cameras and other measures are installed as deemed necessary.

Access under Article 8 of the Additional Protocol

The Additional Protocol grants the IAEA, under Article 5, the right to short-notice complementary access visits (CAs) to any place on the Fukushima Dai-ichi site to assure the absence of undeclared nuclear material and activities. However, Article 4 of the Additional Protocol stipulates that the implementation of CAs shall not be mechanistic or systematic, and instead should be selective; i.e., CAs under Article 5 should not be routine, and to the same locations on a site.

In order to enhance the ability of the IAEA to have short-notice access to locations of interest (*strategic points)* on the site, the Government of Japan has invited the IAEA to perform routine CAs on an on-going basis under Article 8 of the Additional Protocol. The access provided by these Article 8 CAs help the IAEA to assure the absence of undeclared nuclear material and activities, in particular to confirm that there are no indicators of the diversion of the inaccessible nuclear material.

To aid rapid access to the identified strategic points on the site, the specific buildings and locations that can be visited during the Article 8 CAs have been agreed between the Agency and JSGO[9]. Access to the strategic points help the IAEA to confirm the consistency of the operational activities declared in advance by TEPCO.

The provision of access under Article 8 does not impact upon the ability of the IAEA to perform CAs on the site under Article 5.

Other Safeguards Activities on the site

Routine Inspections on the site

A regular inspection regime has been reinstated at Units 5 and 6, and the CSFS, which consists of a physical inventory verification (PIV) inspection once a year, coupled with interim inventory inspections conducted on a randomised basis (random interim inspections, RIIs). Additionally, design information verification (DIV) visits are routinely performed at these facilities. DIVs are also performed at Unit 4, to confirm the closed down status of the facility.

Safeguards for the Transfer of Spent Fuel Assemblies to Dry Storage

TEPCO has constructed a new dry storage cask store on the site, which has allowed long-cooled spent fuel in the CSFS spent fuel pond to be loaded into dry casks, freeing up space for fuel assemblies moved from the other facilities. This new store – the Temporary Cask Custody Area (TCCA) – provides capacity for the storage of up to 65 dry casks. The TCCA was commissioned in March 2013, with receipt of the nine casks from the CCB.

The IAEA verifies fuel assemblies loaded into the dry casks prior to the transfer to the TCCA, and maintains continuity of knowledge of the nuclear material in the stored casks. Once the dry cask is in position at the TCCA, the contents of the closed cask cannot be accessed for verification during the annual PIV of the facility. For such cases, the IAEA requires a higher level of verification of the loaded assemblies than the standard applied to accessible material during the PIV. The instrument used for the verification must be capable of detecting *partial defects* in the fuel assemblies in the form of the undeclared removal of fuel pins.

The IAEA selected the Digital Cerenkov Viewing Device (DCVD)[10] as the instrument for the partial defect verification as, unlike the other applicable NDA methods, the use of the DCVD does not require movement of spent fuel to an underwater detector prior to loading, and therefore minimises the impact upon the transfer operation. Additionally, the use of the DCVD allows the verification of the consignment of spent fuel to be performed once it is loaded into the cask, which reduces the burden on the Operator's campaign schedule.

The verification of the loaded casks at CSFS was the first time that the DCVD had been used for verification in Japan and, prior to the loading campaign, the IAEA and JSGO coordinated training at another reactor site in Japan to best prepare the inspectors for its use. The DCVD is now a standard instrument for verification in Japan when partial defect tests on spent fuel assemblies are required.

Since 2013, there have been two campaigns of dry cask transfers to the TCCA, to make space for the receipt of fuel assemblies from Unit 4 and Unit 3. To date, a total of 28 casks have been transferred, storing 1625 spent fuel assemblies. The transfer of fuel assemblies to dry cask is programmed to continue to allow the receipt of fuel assemblies from the other facilities, and TEPCO plans to increase the capacity of the TCCA. The verification of the transfers is an important ongoing component of the IAEA's inspection effort on the site.

Conclusion

The conditions on the Fukushima Dai-ichi site after the March 2011 accident have posed unprecedented challenges to IAEA safeguards. Through close cooperation with JSGO and TEPCO, the IAEA has been able to adapt the SG measures throughout the changing conditions on the site as decommissioning progresses. This has resulted in the reverification by the IAEA of more than 80% of the fuel assemblies that were on the site at the time of the accident. To support the reverification, the IAEA has developed new technologies and techniques to verify fuel from the damaged reactors.

It is recognised that the decommissioning operations on the site are complex, with many unique challenges, and will require many years to complete. In response, the IAEA has developed innovative technological and access measures designed to enable the IAEA to provide assurance of the non-diversion of nuclear material to non-peaceful activities, notwithstanding the presence on the site of nuclear material that is not yet accessible for reverification.

The IAEA, with support from the Japanese stakeholders, is spending many days of inspector effort performing verification activities on the site. Additionally, significant effort is spent performing office-based work, for example conducting continued analysis of information and data, and preparing for new activities and measures. The significant challenges remaining require close and frequent collaboration with JSGO and TEPCO, as the need to safeguard the removal and storage of fuel debris has never before been encountered by the IAEA.

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[1] The Unit 3 core contained 32 MOX assemblies that had been loaded in 2010. No fresh MOX assemblies were stored at the facility in March 2011.

[2] The accident at Chernobyl occurred prior to the signing of the CSA between Ukraine and the IAEA, which came into force in January 1998.

[3] Further information regarding the decommissioning project on the site can be found on the TEPCO website: https://www.tepco.co.jp/en/hd/decommission/index-e.html

[4] While all nuclear material from the Unit 3 spent fuel pond has been reverified, the anomaly on the facility remains active until the still inaccessible material in the core is fully recovered and reverified.

[5] Improved Cherenkov Viewing Device (ICVD): Hand-held light intensifying analogue device optimized to view Cerenkov light (near ultraviolet) in a spent fuel storage pond. Primarily used to verify irradiated LWR (light water reactor) fuel assemblies.

[6] Next Generation Cherenkov Viewing Device (XCVD): Hand-held high sensitivity light intensifying digital device optimized to view Cerenkov light (near ultraviolet) in a spent fuel storage pond. The XCVD can enhance images via real-time digital processing (image stacking), and can record individual scans for subsequent re-analysis. The high sensitivity and image stacking enables the verification of long-cool and/or low burn-up spent fuels, which previously would have required underwater NDA methods.

[7] Irradiated fuel attribute tester (IRAT): CdZnTe based γ ray energy spectra detector system used for verifying fission product presence in an irradiated fuel assembly.

[8] Subsequent to the IAEA inspection, TEPCO has developed and employed devices to remove the fixed deposits, which allow the serial numbers of these assemblies to now be read.

[9] In addition, provision has been made for the Agency to announce on the day of the CA a visit to locations that are not on the agreed list, with the acknowledgement that access to locations never accessed before might be delayed or postponed for safety reasons.

[10] Digital Cerenkov Viewing Device (DCVD): Rail-mounted highly sensitive digital device optimized to view and record Cerenkov light (near ultraviolet) in a spent fuel storage pond. Contains analysis software to identify missing pins and to quantify the Cerenkov glow from spent fuel assemblies as a function of irradiation history and cooling time, allowing comparison with the Operator's declaration.