J-MOX Project: Synergies among stakeholders in the deployment of safeguards systems during construction

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Abstract
J-MOX is a mixed-oxide (MOX) fuel fabrication plant currently under construction in Japan and co-located with the Rokkasho Reprocessing Plant on the same site. In 2005, the IAEA launched a project within the Department of Safeguards with the objective of developing an effective and efficient approach for applying safeguards to J-MOX. The J-MOX Project developed an approach that includes extensive joint-use unattended non-destructive assay and containment and surveillance systems. The safeguards systems will be owned and maintained by either the IAEA, the Japan Safeguards Office (JSGO) or the operator Japan Nuclear Fuel Limited (JNFL).

J-MOX construction began in October 2010, but was suspended in 2011 after the Fukushima Dai-Ichi accident. Construction restarted in September 2022 following approval by the Japanese safety authorities, and development activities related to the safeguards systems resumed alongside the restart of construction. JNFL now targets completion of construction in the second half of 2024. The J-MOX Project has been restructured in order to meet the challenging safeguards equipment installation timeline with the available resources. This includes continuous interactions with JSGO and JNFL in order to efficiently manage the numerous interfaces among all stakeholders. This paper will provide an overview of the tasks, functions, challenges and accomplishments of the IAEA's J-MOX Project.

Introduction
J-MOX is a MOX fuel fabrication plant currently under construction on the same site as the large scale Rokkasho Reprocessing Plant (RRP) in north-eastern Japan. The maximum annual design capacity of J-MOX is 130 tons of heavy metal. The plant will utilize the MOX powder that is produced from RRP to produce MOX fuel assemblies for pressurized water reactors and boiling water reactors in Japan. Upon commencement of operations, the plant will be one of the most complex facilities subject to IAEA Safeguards, alongside RRP.

J-MOX is designed to have a fully automated fuel fabrication process. Given the complexity and high throughput of the planned facility, the safeguards systems need to be optimized for cost and performance effectiveness. The J-MOX Project developed an approach that includes extensive joint-use unattended non-destructive assay (NDA) and containment and surveillance (C/S) systems with remote data transmission (RDT), and data evaluated using automated software i.e., Near Real Time Data Analysis (NRTA) and Near Real Time System (NRTS). The safeguards equipment will be owned and maintained by either the IAEA, the Japan Safeguards Office (JSGO) or the operator Japan Nuclear Fuel Limited (JNFL).

The IAEA's J-MOX Project Board, the J-MOX Working Group (J-MOX WG) and the Joint Technical Committee (J-MOX JTC) foster communication and collaboration among the stakeholders, and serve as platforms for monitoring the progress and ensure timely delivery of the project. This paper will provide an overview of the tasks, functions, challenges and accomplishments of the IAEA's J-MOX Project during the facility construction stage.

Key Stakeholders and Their Roles

JNFL is the owner and operator of J-MOX. The JSGO, an organization under the Nuclear Regulation Authority (NRA), is responsible for safeguards implementation at J-MOX with support from its technical support organization, the Nuclear Material Control Centre (NMCC). The IAEA independently verifies the declarations provided by Japan, and ensures that Japan fulfils its safeguards obligations.

During the construction stage, JNFL is to provide all safeguards relevant information to the JSGO and IAEA, including the construction schedule, facility design information, information relating to the operator's measurement systems and accountancy procedures. The inspectorates conduct Design Information Examination (DIE) and Design Information Verification (DIV) periodically on-site to assess if the State has provided all necessary descriptive and technical information required by the IAEA to plan and implement Safeguards, to confirm the construction status and to confirm that the plant is constructed as designed.

The IAEA utilizes the information provided by the operator, and information gathered from in-field activities for the development of the facility safeguards approach which determines the safeguards systems to be implemented. The stakeholders share the responsibility for developing the equipment identified for these safeguards systems. In addition, JNFL supports the installation of the equipment before the plant starts operation.

IAEA J-MOX Project

In 2005, upon the provision of the initial design information, the IAEA established a 'J-MOX project' within the Department of Safeguards, including creating a Project Board led by the Deputy Director General of Safeguards (DDG-SG) to provide internal oversight and guidance on the high-level tasks defined for the project. The tasks include the development of the J-MOX safeguards approach, in line with the Japan State-Level Safeguards Approach (SLA), development and implementation of DIE and DIV procedures, and development of safeguards systems.

The Division of Operations A (SGOA) and the Division of Technical and Scientific Services (SGTS) are the main stakeholders of the J-MOX project, with support from the Division of Information Management (SGIM), the Division of Concepts and Planning (SGCP), the Office of Safeguards Analytical Services (SGAS) and the Division of Information and Communication Systems (SGIS) to perform all necessary tasks.

In addition to the Project Board, the following advisory bodies and committees are consulted as applicable:

- The J-MOX JTC composed of Japanese stakeholder representatives (JSGO, NMCC, JNFL) and the IAEA to ensure that key stakeholders are informed of progress and to address any significant project developments and/or risks related to development of the safeguards equipment, systems and software.
- The J-MOX WG composed of Japanese stakeholder representatives (JSGO, NMCC, JNFL) and the IAEA to ensure that the key stakeholders are informed of progress and to

address any significant project developments and/or risks related to subjects such as safeguards approaches, implementation procedures, facility attachment, design information verification and so on.

- The Safeguards Technical Review Committee (TRC) is a standing body composed of departmental representatives (SGCP, SGAS, SGIM, SGIS, SGTS, the Section for Safeguards Programme Coordination, and all Safeguards Operation Divisions) responsible for advising the DDG-SG on the technical aspects of safeguards implementation. They will review the J-MOX safeguards approach and other related technical documents as required.
- The Japan State Evaluation Group (SEG) composed of departmental representatives (SGOA, SGIM) to review the J-MOX safeguards approach, implementation procedure, facility attachment and other relevant documents. The SEG is responsible *inter alia* for preparing and maintaining the Japan SLA.

Challenges and Synergies Among Stakeholders

<u>Current Challenges</u>

Safeguards Approach
Currently, the IAEA is in the process of revising the J-MOX safeguards approach, which was first drafted in 2006, in order to align it with the technical objectives and performance targets defined in the latest SLA for Japan. The safeguards measures, including the equipment are defined in the approach. The main principles include: All nuclear material inventory to be verified at Physical Inventory Verification (PIV); for timeliness, nuclear material containing plutonium in bulk form to be verified at Interim Inventory Verification (IIV), and nuclear material flow from receipt of MOX powder from RRP, within the process and transfers to and from interim storages to be continuously monitored and/or verified using joint-use unattended NDA and C/S; and data evaluated using automated software i.e., NRTA and NRTS. The approach is currently under an internal iterative review process which involves the Japan SEG and subsequently, by the Safeguards TRC. The draft safeguards implementation procedure based on the safeguards approach is under negotiation with JSGO and NMCC.

Safeguards Systems
The safeguards systems to be implemented in J-MOX must be compatible with an automated facility operation, and have the ability to measure nuclear material in different physical forms. Most of them will be operated in unattended mode, which means data is automatically collected and being remotely transmitted to a central server.

Based on the safeguards approach, more than 20 unattended NDA systems and more than 50 surveillance cameras will be installed and data transferred by RDT. NRTA and NRTS are designed to support the inspectorates and to allow remote monitor and/or verification of the inventories and flows of nuclear material through the fuel fabrication process. Together, the safeguards systems help minimize the intrusiveness of safeguards implementation during facility operation. Figure 1 provides an overview of the J-MOX safeguards systems and equipment.

The equipment development and implementation responsibility are split among JNFL, JSGO and IAEA. Each stakeholder engages their own contractors and/or suppliers to develop, procure, manufacture and test their respective safeguards equipment. The standardization of the design of the components and software for data acquisition allows efficient integration of the various safeguards systems and reducing the overall cost for installation and maintenance.

In addition, the shared safeguards equipment must comply with IAEA's requirements for joint use with an external party. IAEA must be involved in all steps (requirements, design procurement, installation, testing, usage and maintenance) of the review and approval process, which is the primary task of the J-MOX JTC. For example, the Glove Box Unattended Assay and Monitoring system (GUAM) which is an operator system, the IAEA needs to determine how the electronic signals could be securely split and the data be authenticated, in order to allow the IAEA to independently draw safeguards conclusions.

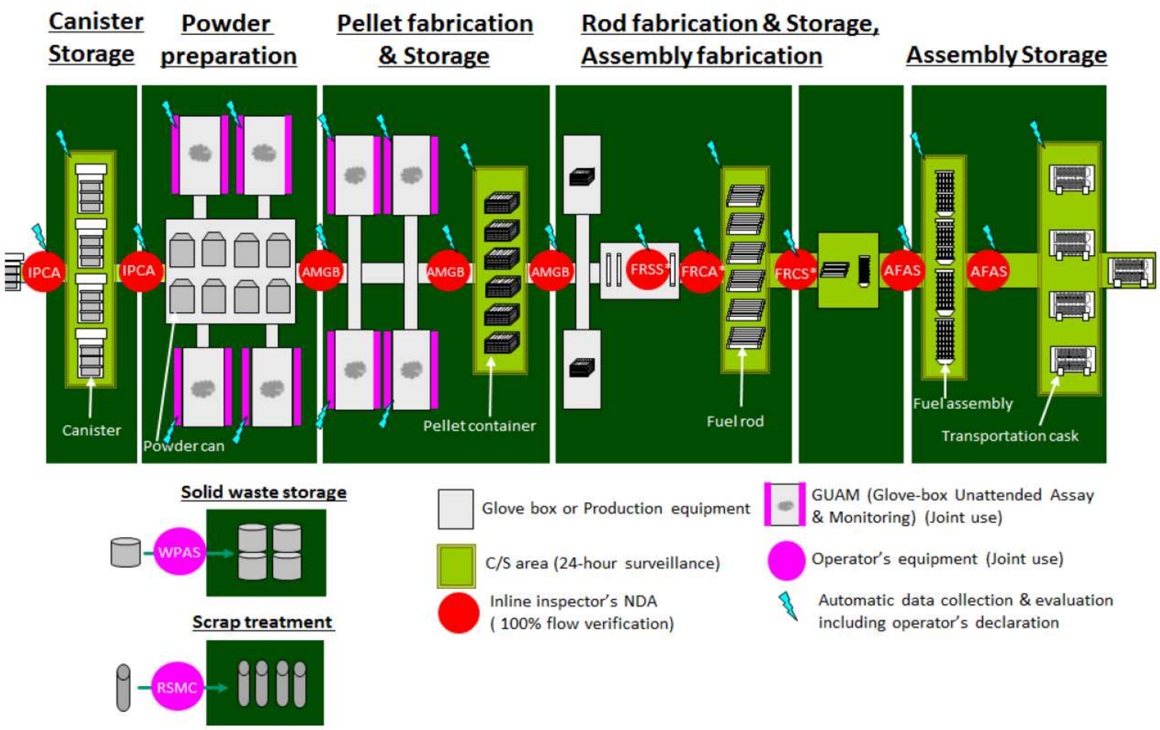

Figure 1: Overview of J-MOX safeguards systems and equipment, which are jointly used by JNFL and the inspectorates

Construction Schedule

J-MOX construction began in October 2010, with the initial plan to complete the construction in 2012. The construction was then suspended in 2011 after the Fukushima Dai-Ichi accident. Between 2012 and 2022, construction was mainly limited to the foundations of the main process building. The construction of the building itself was postponed awaiting further authorization by the NRA based upon updated safety regulations introduced following the accident at the Fukushima Dai-ichi nuclear power plant. In the meantime, the construction of the utilities building was completed.

The construction of the main process building restarted in September 2022. Figure 1 shows the construction at J-MOX in 2024. The installation of equipment, including IAEA's safeguards systems, is not permitted until NRA completes the relevant safety reviews and grant the approvals. This suggests a potential delay in the completion of construction. This will also impact IAEA's planned timeline on the delivery of the safeguards systems in J-MOX. The overall construction schedule is under re-consideration by JNFL.


Figure 2: MOX Fuel Plant Construction June 2023 at JNFL 1 site (credit Japan Nuclear Fuel Limited).

Budget and Resources
The original cost estimate for the project was based on the planned start of operations in 2012. Inflation over the last 10 years needed to be factored into the present-day cost estimates. Following the restart of the construction in 2022, the IAEA reassessed the spending and resource plans for the project's lifespan to align with the operator's schedule.

Currently, the IAEA has dedicated additional resources, both human and financial, in order to deliver the project in accordance to the operator's official schedule. If there are delays, the staffing period will need to be extended, which will require additional funds.

As for the equipment that will or has been shipped, the JNFL will need to provide proper interim storage in order to prevent hardware degradation caused by environmental conditions. Depending on the length of construction delays, the factors such as equipment aging and software being outdated by the time the facility starts operation will need to be considered as well. Additional budget will be needed for subsequent maintenance, upgrade and replacement of equipment and software prior to installation. For the surveillance cameras, the risk is low, as they can be deployed to other facilities and the stock can be replenished later.

<u>Synergies Among Stakeholders</u>

Advisory Bodies and Committees
The RRP experience has shown that the effective and successful development of the safeguards equipment and software for large facilities can only be achieved through a comprehensive design which focuses on an integrated system rather than the collection of individual components. The design complexity is increased by the fact that the equipment and software are developed by different stakeholders, who in turn are assisted by numerous developers/manufacturers from

around the world. Therefore, strong technical cooperation is needed in order to streamline the development, and optimize the standardization of equipment and its ability to be integrated, in order to reduce the risk of reworking and minimize the overall costs.

The J-MOX JTC, which was established in early 2006, is the platform that focuses on such collaboration and discusses technical issues related to joint-use software and equipment, and integrates the lessons learnt during RRP equipment development and testing. The requirements, conceptual designs, test plans, test results, maintenance plans and documentation for joint-use hardware and software are reviewed and approved by the committee prior to the next stage of development, fabrication, or acceptance proceeds.

The J-MOX WG and JTC meet twice a year, mostly on-site at Rokkasho to allow the maximum participation from the Japanese stakeholders. Equipment and software developers/manufacturers are also invited to the progress review meetings or video conference meetings, as necessary. For example, Japan Atomic Energy Agency (JAEA) (who supports the JSGO/NMCC/JNFL in the development and testing of unattended NDA systems and data acquisition systems for J-MOX) participates in the JTC meetings to report the results of the tests that they have performed, and discuss the scope of testing according to the needs of the stakeholders.

Action lists are created, reviewed and updated for all the meetings between the stakeholders. In addition, for WG and JTC meetings, the discussions are recorded in the minutes of the meetings. These documents are shared with the stakeholders, where they jointly keep track of the project development and ensure that the project can be timely delivered.

Member State Support Programmes

Through the Member State Support Programmes (MSSP), the IAEA has obtained:

- Technical support for the development of NDA equipment from USA (Los Alamos National Laboratory (LANL)) and the European Commission (EC);
- Technical support for the testing of NDA equipment and/or prototype in Japan (Japan Atomic Energy Agency (JAEA)), EC, and France (MELOX); and
- Cost-Free Experts (CFE) from France, USA and most recently from Japan. All whom have relevant technical backgrounds or experience relating to MOX fuel.

Some safeguards equipment, such as the Fuel Assembly Assay System (FAAS), Material Accountancy Glovebox System (MAGB), and the Plutonium Canister Assay System (PCAS) are currently used in the Plutonium Fuel Production Facility (PFPF), which is a JAEA facility in Japan. Based on the inspectorate’s usage experience, the designs of these systems have been improved and adapted for J-MOX. The Advanced Fuel Assembly System (AFAS) which can measure both PWR and BWR fuel assemblies is being tested in PFPF. The Improved Plutonium Canister Assay System (IPCA) is being tested in LANL.

The IAEA recently requested for support from US support programme and MSSP to collaborate with LANL in the development of an effective and efficient joint-use approach for the GUAM. The system is being developed by LANL under contract with JNFL and will measure glove box holdup at J-MOX. The IAEA would like to collaborate with LANL in the development and assessment of potential methodologies aimed to improve cost efficiency while still maintaining control of detector authentication.

This support in kind, apart from benefiting from expert knowledge, allows the IAEA to reallocate the budget to other parts of the J-MOX project, e.g., procurement and manufacturing of the safeguards systems which could be performed in-house for further cost reduction.

Strategies for Improving Stakeholder Collaboration

Following the restart of the construction in 2022 and new construction completion date, the J-MOX project was restructured in order to meet the challenging safeguards equipment installation timeline with the available resources. A project coordinator is appointed in SGOA to assist the J-MOX project team to manage the administrative matters (budget and resources) and coordinate among the internal project members from the operations division, technical services, information services, information management and analytical services.

In January 2024, a CFE from Japan joined the IAEA and is now providing important support to the J-MOX project. He was working previously on the J-MOX project at JNFL. As a CFE at the IAEA, he assists the IAEA team on the technical aspects of the J-MOX project, such as reviewing the technical documents and drawings, and providing clarification necessary for the IAEA to proceed with equipment development.

Given the fact that the stakeholders come from diverse backgrounds, different cultures, and speak different languages, the CFE assumes a very important role, acting as a bridge to facilitate communication and discussions between IAEA and the Japanese stakeholders. This helps to minimize any confusion or misunderstandings that may arise.

In addition to J-MOX JTC, bi-weekly working level meetings via video conferencing started in 2023 to enhance the cooperation and allow more frequent exchanges between the JSGO, JNFL and IAEA. At the request of the IAEA, JNFL shared 3D representations and organized 3D virtual "tours" during the bi-weekly meetings to help the project team visualize selected locations in J-MOX. The stakeholders can jointly determine and agree on the suitable locations for equipment installation, without having to wait for the building or a specific location to be physically built. Figure 3 shows an example of a 3D representation of gloveboxes in a process area.

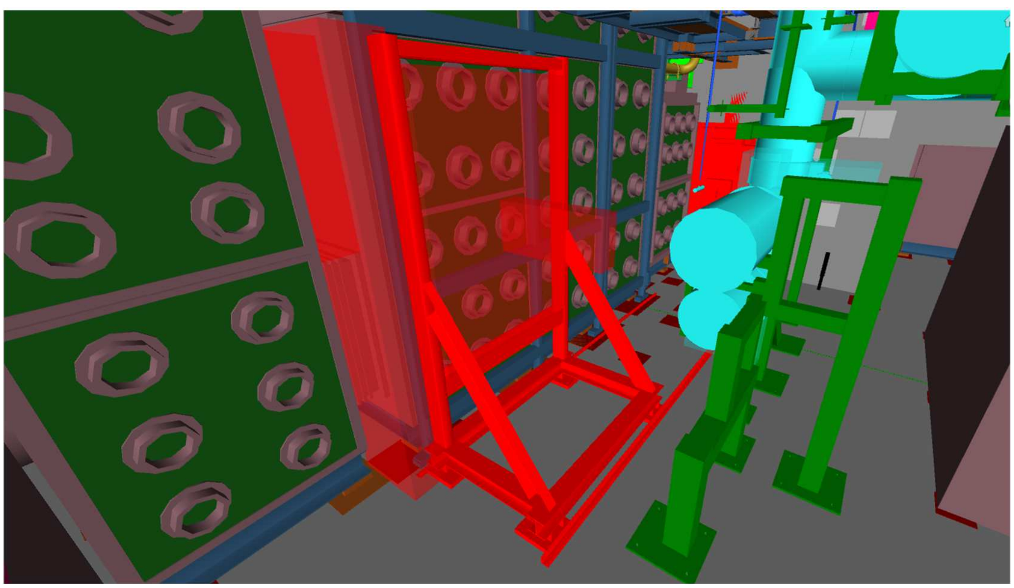

Figure 3: 3D representation of Advanced Material Accountancy Glove Box NDA system.

Conclusion

The J-MOX is a large and complex facility. It is not possible to safeguard such a facility without establishing an integrated approach and sharing of resources from all stakeholders. Such an approach was decided at the earliest stage of the project. The IAEA's experience from the RRP project has shown that strong technical coordination and close synergies among the various stakeholders are imperative to the successful development and implementation of safeguards systems. This cooperation and collaboration have become even more crucial considering the challenges faced by the IAEA, which include a stringent operator construction schedule and resources made available for the J-MOX project.

To ensure the timely deployment of the safeguards systems during construction, each stakeholder is assigned clearly defined roles and responsibilities. It establishes a clear structure for effective communication and collaboration towards achieving the project milestones. With established communication channels, it helps sharing of information, building trust and fosters better collaboration among the stakeholders. Regular meetings are scheduled, both in-person and virtual (WebEx, emails) to foster interactions and discussions. The meetings provide opportunities to address questions, resolve issues, align project objectives and progress. Support from external parties is valuable in terms of getting expert advice, and allows reallocation of resources to develop other areas of the project.

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