

# Development on a Regulatory Frameworks of the Remote Inspection System for Nuclear Safeguards

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## 1. INTRODUCTION

- Small Modular Reactors (SMRs) are characterized by multi-module configurations, resulting in distributed nuclear material inventories, asynchronous refueling cycles and reduced operational staffing.
- These features might increase the physical burden on inspectors under traditional periodic on-site systems. Continuous validation using unmanned remote systems and equipment (Robot, Drone, DT-BC) should be added to minimize monitoring gaps and maintain continuity of knowledge (CoK).
- Accordingly, **this study proposes a regulatory framework for Remote Inspection to minimize verification gaps arising from these SMR characteristics and to support efficient safeguards implementation.**

## 2. INSTITUTIONAL & TECH TRENDS

### ◆ IAEA Safeguards Glossary (2022):

Clarifies Near Real Time System (NRTS), Mailbox declarations and Unattended Monitoring System (UMS) as concepts supporting near real-time data submission and unattended monitoring, and describes the SNRI\* approach for 100% verification coverage.

\* SNRI: Short Notice Random Inspection

### ◆ International Trends (IAEA STR-409):

Highlights the development of advanced remote and autonomous verification capabilities, including tools such as the Robotized Cerenkov Viewing Device (RCVD), to improve inspection efficiency and safety [3].

### ◆ Domestic Research :

- (2014) Automated quality check software for mailbox declarations has been developed to detect errors before submission and improve data quality [4].
- (2025) Digital Twin and Blockchain(DT-BC)-based system is being developed for nuclear material accountancy to improve traceability and data integrity [5].

## 3. PROPOSED FRAMEWORK

### ◆ Concept of Remote inspection

- Remote inspection extends the SNRI concept to SMRs using NRTS to maximize verification coverage while minimizing physical burdens.
- By integrating DT-BC automated systems, operators submit Mailbox declarations and support regulatory verification to maintain CoK.

### ◆ Regulatory Framework

- **Legal Basis:** Proposes a "Remote Inspection" category in NSSC Notice No. 2025-2 to recognize digital data as legitimate evidence.
- **Operational Objective:**
  1. Improve inspection efficiency in routine inspections
  2. Support timely ad hoc verification through near real-time monitoring
- **Notification:** Adopts a  $\geq 2$  hours notice requirement (from [1] Article 6) to ensure procedural legitimacy and secure access.

Table 1. Comparison of Existing Inspection Types [1] and Proposed Remote Inspection

Type	When	Purpose	Frequency	Notification
Initial 반입 전 검사	Prior to initial receipt	Pre-receipt verification	One-time	$\geq 10$ days
Routine 정기검사	Periodic	Implementation verification	$\geq 1/\text{year}$ ( $\leq 14$ months)	$\geq 10$ days
Ad Hoc 수시검사	As needed	Implementation review	Not fixed	As provided in the regulation
Special 특별검사	Specified conditions	Verification of special reports or non-compliance	Not fixed	As provided in the regulation
Remote 원격검사	As needed	Support for timely detection and efficient inspection	Not fixed	$\geq 2$ hours

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## 4. INSPECTION METHODOLOGY

### ◆ DT-BC Architecture

**Digital Twin:** 3D visual verification of fuel movement history.

**Blockchain:** Temporal traceability and record falsification prevention.

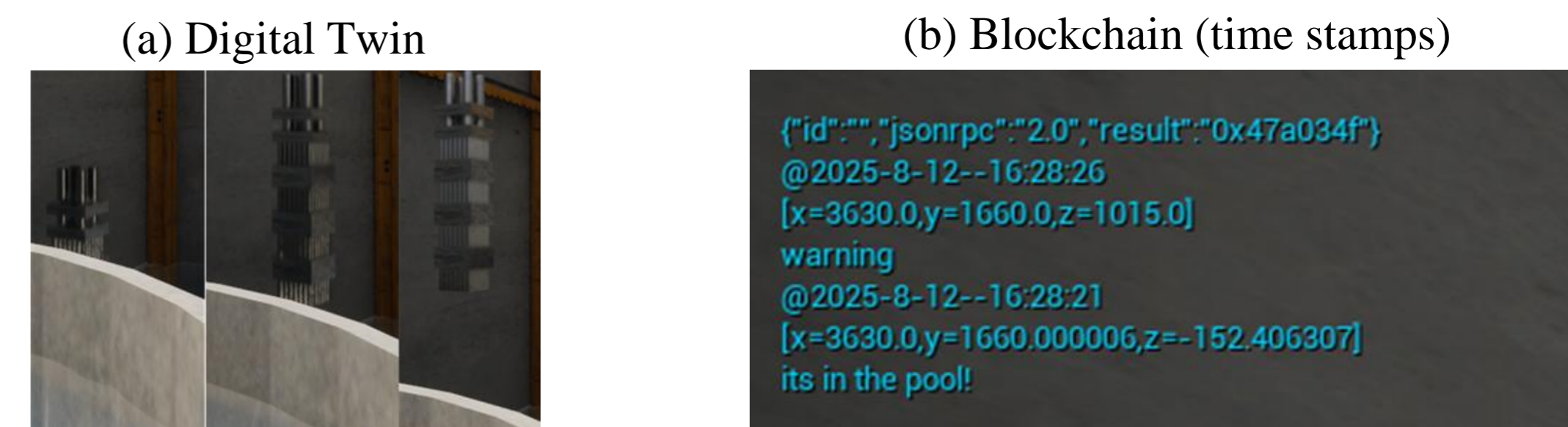


Figure 1 : Example of Fuel Movement Simulation in DT – BC [5]

### ◆ Remote Inspection Framework for the State regulator :

Supports efficient safeguards implementation using remote systems and equipment.

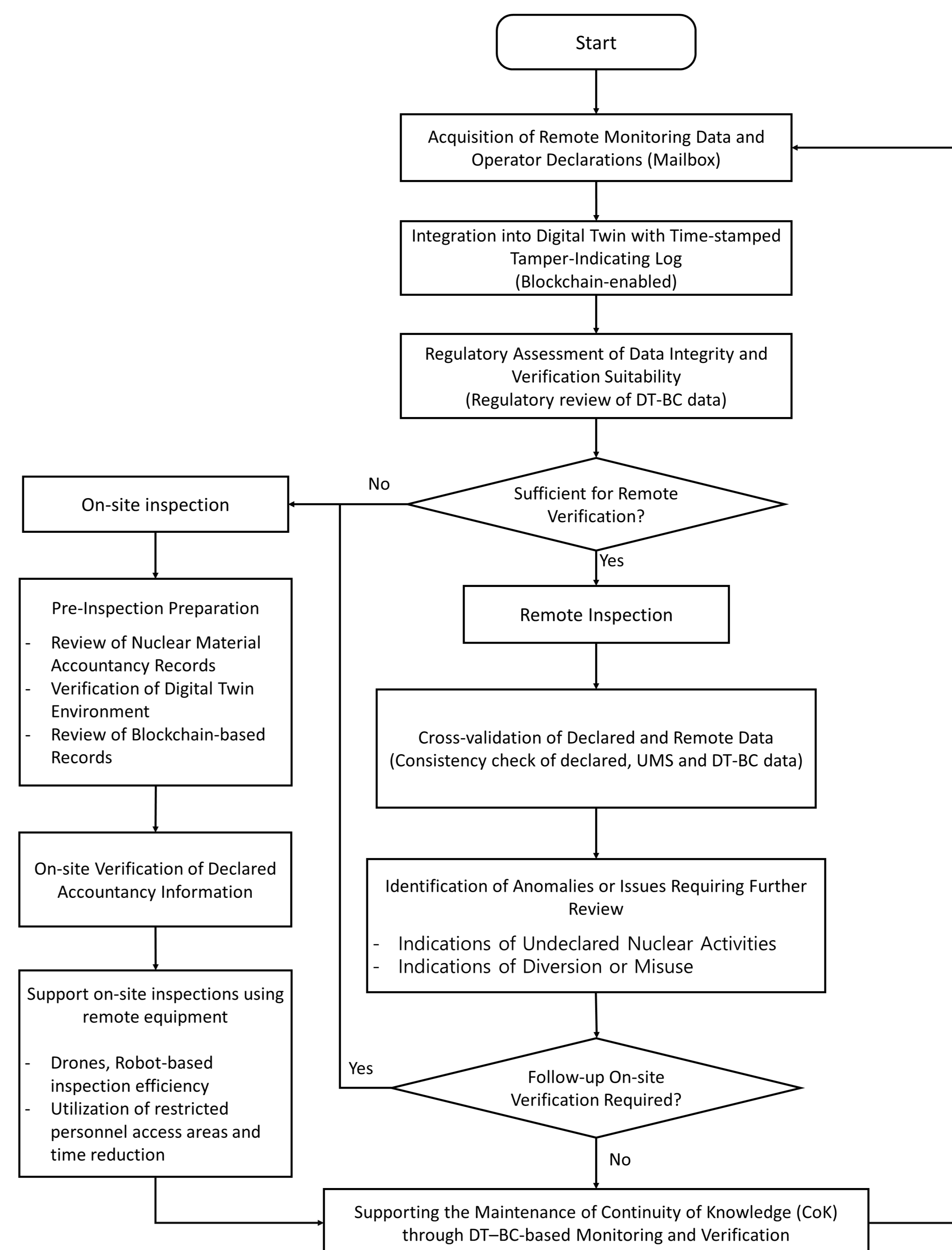


Figure 2 : Schematic Diagram of the Remote Inspection Procedure

## 5. CONCLUSION

- This study proposes a Remote Inspection regulatory framework under NSSC Notice No. 2025-2 as a complementary means to support SMR/AR safeguards.
- **The proposed framework complements on-site inspections through continuous remote verification, reducing verification gaps and supporting timely detection.**
- But final judgement and responsibility remain with the state regulator.
- The system also supports CoK maintenance in multi-module environments with asynchronous refueling and complex inventories.
- As SMR deployment expands, it is expected to improve reporting and inspection efficiency while reducing time and cost burdens.

## REFERENCES

- [1] Nuclear Safety and Security Commission, Regulation on Nuclear Material Accountancy Inspections, NSSC Notice No. 2025-2, Republic of Korea, 2025.
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