Digitising the waste handling supply chain for the long-term: a real-world case study

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ABSTRACT

Sellafield Ltd, Digital Catapult and RKVST recently worked on a project to explore how innovations in distributed ledger technology (DLT) could be used to solve current and future nuclear industry challenges. The project successfully demonstrated how digitizing the process would save time, eliminate transcription errors and significantly reduce the long-term cost. Over the next 120 years, Sellafield is committed to decommissioning and rendering safe an estimated 1.8 million tonnes of nuclear waste derived from facilities that date back to the 1950s. Data from today will be essential information for nuclear workers in the twenty-second century and beyond.

Locating and tracking nuclear waste requires significant effort, involving the manual coordination of multiple entities and actors across the nuclear waste management lifecycle, querying and updating information in dispersed data silos, and continually ensuring compliance in an evolving regulatory landscape.

The primary goal of the nuclear waste tracking challenge was to build a working prototype for a digital solution that would:

- Provide global waste asset visibility
- Ensure compliance with waste acceptance criteria
- Allow device-agnostic access
- Deliver continuous information assurance with accessibility, security, and resilience
- Integrate with industrial internet of things (IoT) sensors
- Result in cost savings and process improvements

This session explains how the multi-stakeholder physical processes associated with nuclear waste handling were mapped into digital data flows and brought to bear on problems of data security, long term integrity, and changing regulatory landscapes.

I. The Nuclear Waste Challenge

In 2020, RKVST (pronounced "Archivist") partnered with Sellafield and Digital Catapult, the UK authority on advanced digital technology, on a nuclear waste challenge: how can distributed ledger technology (DLT) coordinate data exchange, ensure data consistency and data longevity within the highly regulated nuclear waste handling cycle? The digital solution needed to represent the single source of truth from the generation of waste and containers to geological disposal. The integrity of information also had to be maintained over extended timescales (decades to centuries) and across different stakeholders and evolving government policies.

Sellafield is the largest operation under the UK's Nuclear Decommissioning Authority (NDA), hosting 73 percent of the UK's nuclear waste inventory.[1] It is the home of the UK's oldest nuclear facilities and is the only NDA organization that manages all three forms of nuclear waste (low, intermediate, and high).[2] The majority (93 per cent) of waste at Sellafield is intermediate level waste.[3] Overall, Sellafield's waste volumes are expected to increase from 202,000 cubic meters in 2019 to 4.3 million cubic meters by 2135.[4]

Nuclear waste is packaged into containers which are highly engineered components for the overall protection of the workforce, public, and the environment from the radioactive waste contained within them. Records accompanying containers are equally important as they prove whether the container is suitable to maintain its function. These records include extensive metadata related to the waste container, its manufacture and handling as well as information regarding its contents.

The current ability to locate and track nuclear waste moving through Sellafield and the NDA estate requires significant effort involving multiple actors, siloed databases, and legacy systems. With one in five steps of the nuclear waste tracking process relying on paper or manual steps, the solution had to:

- Provide global waste visibility;
- Deliver continuous information assurance with accessibility, security, and resilience;
- Integrate with existing internet of things (IoT) sensors;
- Allow device-agnostic access;
- Ensure compliance with waste acceptance criteria;
- Result in cost savings and process improvements.[5]

II. RKVST and Blockchain

Blockchain is a subset of distributed ledger technology (DLT) which is the catch-all category for decentralized digital databases that can include a wide range of participants and data sources from multiple locations. The RKVST platform uses a privately hosted instance of the Quorum network which is derived from the Ethereum blockchain - a permissioned, or private, DLT that supports data privacy. Blockchain records signifying real world assets on the RKVST platform are each represented by a unique digital twin, which is passed between actors to reflect an asset's live status.

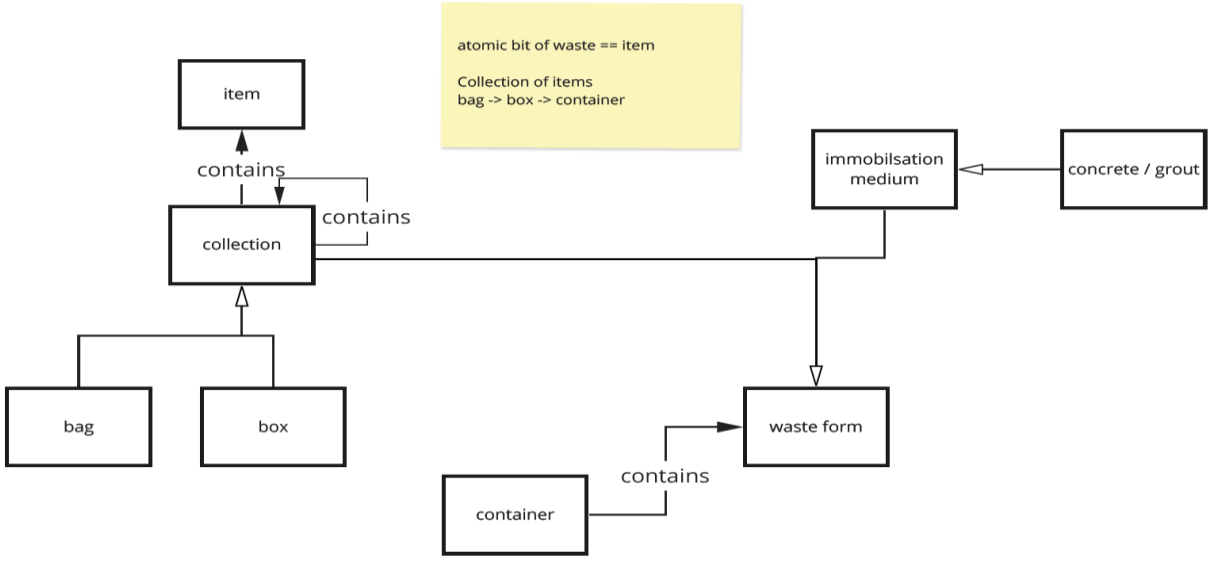
Each twin contains data attributes corresponding to data fields from a traditional record that are made available only to those authorized. This functionality, combined with other webservices, enables the RKVST platform to track and trace all events related to an asset as it moves through the supply chain, process stream, or workflow with permissioned multi-party visibility aligned with regulations and contractual requirements.

The RKVST API enables seamless integration with existing applications and with data on-premises or in the cloud. This makes it easy to add DLT to current systems without having to build in-house DLT capacity including managing, scaling and running more servers, virtual machines (VMs) and storage. It also gives facilities the capability to access and link source documentation with inventory data, replacing a function currently performed manually. DLT helps boost operational efficiency and maintain safety by getting the right data to the right place at the right time in a verifiable form for any supply chain stakeholder making a critical decision.

III. Answering the Challenge

The stages of handling were agreed through a series of collaborative meetings with a focus on low-level waste processes across three stakeholders: Sellafield, the NDA, and LLWR Ltd, which operates the UK's Low-Level Waste Repository (LLWR). An ontology was agreed with minimal complexity to keep the demonstration flexible while still being representative to verify the applicability of DLT and nuclear waste tracking to existing processes: items go into collections; collections go into containers; and containers move according to the waste acceptance criteria (WAC) as outlined in Figure 1.

Figure 1. Ontology Nuclear Waste Tracking



Three factors were agreed to be proven:

- Tracking related items in the system. Packaging and unpacking hierarchies of items must be supported;
- Multiple stakeholders able to view and track items;
- Possible to encode digital and physical assets. WAC for facilities need to be tracked in the same handling record as the items they apply to.

The RKVST API captured data across the NDA estate without changing existing databases or data capture techniques to provide a single source of truth. RKVST pulls information from multiple authorized sources to provide a consolidated overview of the entire estate, providing visibility of the waste lifecycle, characteristics, and waste inventory all in one place for stakeholders to view and query in line with access controls and confidentiality rules. Behind the scenes the timestamps, identity details, and the actual data are all cryptographically protected, and verifiable, providing data integrity and traceability across the NDA estate with an immutable record of what happened, when it happened and who was responsible.

The RKVST platform enabled facilities to access and link source documentation with inventory data and Sellafield was also able to append additional information to any asset record including scanned documents, GPS data, quality reports, IoT metrics, etc. RKVST makes linking physical and virtual assets simple by having a consistent, reliable, global identifier for the virtual asset which can be represented by a physical QR codes that travels with the container (or its paperwork). This demonstrated real-time operational collaboration between multiple parties located in different jurisdictions using different types of terminals with (potentially) different access rights. This in turn proved the RKVST's platform integration with real-world workflows and enabled a mobile experience without the need for an app to install. Digital Catapult's DLT Field Lab estimated that RKVST improves more than 55 per cent of current process steps and reduces information mismanagement by 90 per cent.[6]

Recognizing that standards and regulations change over time, RKVST demonstrated how encoding regulations and other important criteria (such as Waste Acceptance Criteria) makes it simple to check for compliance – no matter whether the asset, process or rules have changed. All three can be compared in near-real-time. It therefore allows the inspection of historic data ("what did this item look like three years ago?") and retrieval of historic regulatory guidance ("what were the regulations three years ago") for quick and confident reviews for historical compliance (was it a good idea at the time?").

IV. Future Proofing

Cryptographic security is often explained in terms of the 'CIA triad,' which represents the three fundamental needs of cryptographic systems and determining the impact of an attack involving some data, as well as data protection controls:

- Confidentiality: can you keep things secret so that unauthorized parties can't seem them?
- Integrity: Can you prove things are unmodified, and that what you are reading is truly what was sent to you?
- Availability: Can you ensure that the data is still available when needed? If you forget your password, have you lost the data forever?

The distributed and decentralized nature of DLT-based platforms already provides for improved integrity by making it very easy to spot falsified records. With the added protection of chained cryptographic hashes and signatures, it is possible to upgrade protection along the way as the technological landscape changes. With DLT still a new technology (15-16 years young) and evolving rapidly, there are several areas that could lead to future-proofing problems without careful design. RKVST, with its hybrid webservice + DLT architecture, insulates customers from most of these issues by using an abstraction layer and loose coupling to the DLT which enables the platform to evolve with the state-of-the-art without disrupting end-users. RKVST's tech stack also follows larger communities that are actively developing and updating tooling and software, such as Microsoft Azure services for performance and security and Quorum blockchain for the DLT layer. Although Quorum at 6 years old is not as old as Microsoft's 47 years, it was developed by J.P. Morgan as a step towards common adoption of blockchain (initially) among financial industries. Quorum is built from Ethereum's base code meaning there will be little to no changes in maintaining the sync between the two if the Ethereum network undergoes different future upgrades,

One of the main pain points for all cryptographic systems is the security of the keys used – a technology that is also rapidly advancing. RKVST uses a corporation's single-sign-on for identify, utilizing existing IT and standards for access without users needing to learn complex key or wallet management techniques. And no need to open device routes to more control systems. The RKVST system used in the DLT Field Lab used Microsoft Azure Key Vault, which enables the use of market-leading hardware security modules in the cloud.

V. DLT and Nuclear Waste Management

Digital Catapult's DLT Field Lab demonstrated that DLT can improve operational efficiency in nuclear waste operations, incorporate legacy systems and eliminate silo-ed data streams. DLT enables organizations to authenticate data and build trustworthy digital supply chains on a single shared ledger that serves as the only source of truth. Coupled with permissioned platforms, DLT enables data access controls to ensure the right people get the right data at the right time along the back-end of the nuclear fuel cycle towards disposal. Stakeholders can then see – and easily query – an event to ensure that what was done at the time complied with the waste acceptance criteria and

national regulations at the time and was the right (or not right) thing to do. Decisions along the supply chain are therefore made more efficient and more operationally-relevant in today's businesses.

RKVST's provenance-as-a-service platform provides tamper-evident, item-level traceability enabling multiparty coordination and visibility of who did what when. This enables organizations to eliminate errors, save time, and significantly reduce costs while permissioned access ensures data sharing is aligned with national rules and regulations. As noted by Dr Robert Learney, the Head of Technology, Distributed Systems at Digital Catapult: "There are wide ranging benefits that distributed ledger technologies can bring to the nuclear industry from securely tracking and monitoring high value assets to ensuring the safety of the workforce on site."[7]

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[1] Department for Business, Energy, and Industrial Strategy and Nuclear Decommissioning Authority, "UK Radioactive Waste Inventory 2022", https://www.gov.uk/government/publications/uk-radioactive-waste-and-material-inventory-2022/uk-radioactive-waste-inventory-2022#_ftn21.

[2] Sellafield, "About Us," https://www.gov.uk/government/organisations/sellafield-ltd/about. Accessed 22 April 2023.

[3] https://ukinventory.nda.gov.uk/site/sellafield/. Accessed 22 April 2023.

[4] Digital Catapult, "Sellafield DLT Field Lab," July 2022, p. 6: https://www.digicatapult.org.uk/expertise/publications/post/harnessing-the-power-of-distributed-ledger-technology/.

[5] Digital Catapult, p. 3.

[6] Digital Catapult, p. 25.

[7] https://www.realwire.com/releases/RKVST-shows-the-future-of-nuclear-waste-tracking-with-Zero-Trust-Fabric