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Development of Nuclear Material Accountancy Software to Enable the Office for Nuclear Regulation to Fulfil Its Role as Nuclear Safeguards State Regulatory Authority in the UK

B. Hughes*, P. Curtis, S. Owen

Office for Nuclear Regulation (ONR), Redgrave Court, Merton Road, Bootle, L20 7HS
*Corresponding Author: ben.hughes@onr.gov.uk

1. Abstract

Following the United Kingdom's withdrawal from the Euratom Treaty, the UK Office for Nuclear Regulation, ONR, has become the UK state regulatory authority for safeguards, working with the UK Government and civil nuclear stakeholders to develop a State system of accounting for, and control of, nuclear material. A key feature of the ONR becoming the safeguards regulatory authority in the UK has been the development of an IT system, the Safeguards Information Management and Reporting System (SIMRS), with nuclear materials accountancy underpinning many safeguards activities. SIMRS provides a solution to receive, consolidate, domestic transit match, interrogate and process nuclear material accountancy reports from UK operators. Additionally, SIMRS produces reports that are required by the UK under new voluntary offer safeguards agreements with the International Atomic Energy Agency and enables reporting pertaining to UK and third-party States under nuclear co-operation agreements. This was a substantial undertaking for ONR against a highly political landscape, with challenging deadlines, multiple constraints derived from an existing extensive, complex, and well established civil nuclear industry, and built from a limited initial base. SIMRS was systematically developed and tested in readiness for live operation as part of ONR's preparations to take on its new regulatory responsibilities in respect of safeguards. This paper provides an overview of ONR's work in developing SIMRS with details and examples relating to optioneering, procurement, testing, stakeholder engagement and management, key challenges, and learning from experience.

2. Introduction

Following the 2016 referendum and the UK decision to leave the European Union (EU) and Euratom, the UK government announced [1] that the UK would establish a domestic nuclear safeguards regime designating ONR as the State Regulatory Authority (SRA). The ONR project to deliver this began in summer 2017, with a delivery date determined by the UK government decision to leave the EU by 29 March 2019, and a subsequent agreement on a transition period up to 31 December 2020 when Euratom provisions in the UK would cease.

Having been regulated by Euratom for nuclear safeguards since 1973, the UK didn't have a comprehensive State System of Accounting for and Control of Nuclear Material (SSAC), prior to leaving Euratom. As a result, ONR needed to establish a nuclear material accountancy system to enable the upload, editing and creation of nuclear material accountancy reports required by the Nuclear Safeguards (EU Exit) Regulations 2019 (NSR19) [2], but additionally, capable of translating those domestic reports into the format required by the UK/IAEA bilateral Voluntary Offer Agreement (VOA) (INFCIRC/951) [3] for submission to the IAEA by ONR on behalf of the UK.

This paper focusses on ONR's work to establish a fit for purpose nuclear material accountancy system for the SRA set against several challenging constraints.

2.1. The Importance of Numbers – Accounting vs. Accountancy

The IAEA Safeguards Glossary [4] describes nuclear material accounting and accountancy as follows:

- Nuclear material accounting:
  "Activities carried out to establish the quantities of nuclear material present within defined areas and changes in those quantities within defined periods"

- Nuclear material accountancy:
  "The practice of nuclear material accounting as implemented by the facility operator and the SSAC, inter alia, to satisfy the requirements in the safeguards agreement between the IAEA and the State (or group of States); and as implemented by the IAEA, inter alia, to independently verify the correctness of the nuclear material accounting information in the facility records and the reports provided by the SSAC to the IAEA"

Both nuclear material accounting and nuclear material accountancy (NMA) are pillars of nuclear safeguards, and the importance of current, accurate, timely and correct NMA underpins domestic and international regulatory compliance, drives inspection activities, and supports international cooperation agreements.

2.2. Safeguards Information Management and Reporting System

The UK Safeguards Information Management and Reporting System (SIMRS) was conceived to address the needs of ONR as the UK SRA to underpin its work in delivering its SRA role and enabling the UK SSAC overall to deliver its domestic and international commitments. Figure 1 below provides a pictorial view of where SIMRS sits both within the UK SRA and UK SSAC, along with the nuclear safeguards' information flows into and out of the UK.

It is important to recognise that SIMRS is exclusively a tool for the UK SRA and not for use by UK facility operators. The concept of a SIMRS "lite" solution to be made available for other UK SSAC constituents (Facilities/Location outside Facilities (LoFs)/UK Government) was considered early during scoping development but was deemed out of scope for the project due to several factors discussed below. However, the software allows for expansion into such in the future should the need arise.

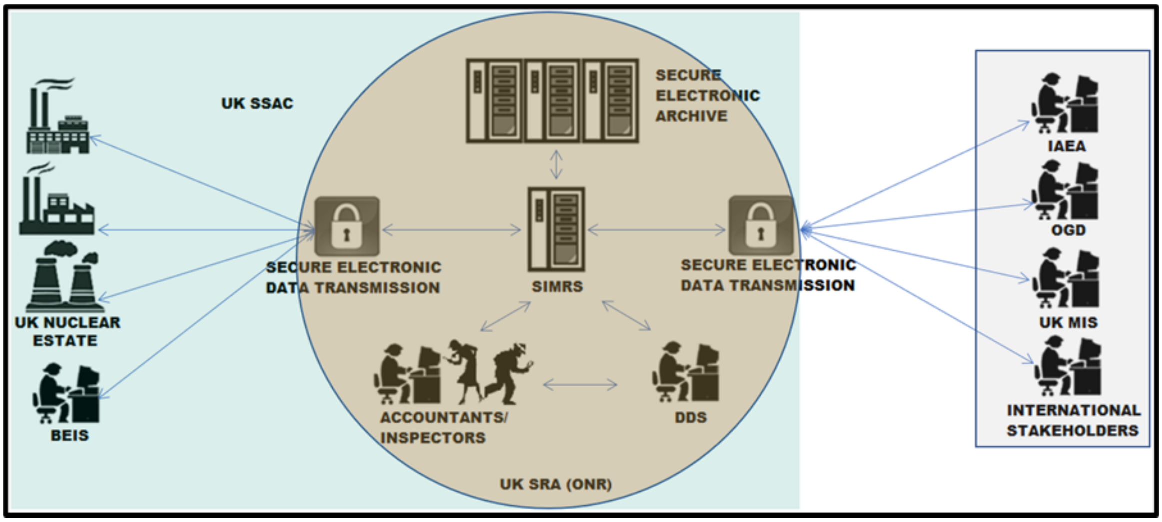

Figure 1. Information flows into and out of SIMRS within the UK SSAC

3. What is SIMRS? – What It Does Do, and More Importantly, What It Doesn't Do

To simply describe SIMRS as a nuclear material accountancy database for the UK SRA to use would not do it justice. The following sections examine what SIMRS can do before exploring some of the limitations and wider dependencies.

3.1. Key Features

The key features of SIMRS are:

- Three-tiered service orientated architecture based upon Microsoft technologies (SQL, XML, DOT NET and ASP.NET) using a browser based front end;
- Accessible to ONR safeguards inspectors and NMA specialists both in the office and in the field using a variety of hardware (laptops/phones/tablets);
- Secure – UK-based hosting platform only accessible using ONR-issued hardware and with disaster recovery back up;
- Development and training friendly – Environments outside of the live production environment (Pre-production and Disaster Recovery) for both user acceptance testing (UAT) of new development revisions and mirrored servers of the live environment for training investigation purposes;
- Ability to process, edit, produce, and validate compliance against both IAEA Code 10 and NSR19 format reporting and associated schemas for inventory change reports (ICRs), physical inventory listings (PILs), and material balance reports (MBRs);
- Ability to convert NSR19 to IAEA Code 10 reports;
- Ability to export XML reports;
- Full traceability of batches between NSR19 NMA reports and IAEA Code 10 format;
- Maintains current book balance of individual batches using criteria such as material balance areas (MBA) and key measurement points (KMP);
- Inventory entries for every facility/LoF defined by key attributes; batch name, MBA, KMP, element, isotope, material description code, etc;
- Retains a complete inventory change history in both NSR19 and IAEA Code 10 formats
- Performs domestic transit matching for all facilities/LoFs in the UK;
- Reliable handling and processing of several hundred thousand nuclear material accounting data entries per year;
- Processes two different correction principles – By Difference Correction Principle (BDCP)
- BDCP and Virtual Replacement Correction Principle (VRCP);
- Provides an audit trail for UK SRA on domestic and international nuclear safeguards accounting information;
- Reconciliation of book accounts against UK Operator declarations;
- Provides intelligence to drive/feed wider regulatory activities; and
- Ability to interrogate declaration data in UK and IAEA Code 10 format to help establish trends and produce bespoke reports.

You may be forgiven for thinking from the above list that SIMRS in and of itself is all that ONR require for NMA. Figure 1 identifies that whilst SIMRS is central to what ONR does, there are many stakeholders required to ensure an effectively performing UK SSAC.

3.2. What SIMRS Does Not Do

Nuclear material accountancy is complex and nuanced. This is further compounded where NMA spans all fuel cycle stages from new build and experimental, to decommissioning and everything in between. Consistency in reporting, adherence to schemas, regulatory rules and formatting go some way to helping but there will always be exceptions to the rule and relying solely upon software will never be the solution. The importance of NMA specialists and inspectors to interpret, analyse and verify the data presented cannot be understated. A number of these areas are highlighted below and illustrate the importance of why all components of the UK SSAC working together is paramount to underpin good practice NMA.

SIMRS does not:

- Identify patterns of Operator reporting behaviour on its own.
- Identify diversion/proliferation pathways.
- “Do” Nuclear Materials Accountancy in and of itself.
- Verify that operator declarations to the SRA match reality – this is the primary driver for in-field SRA accountancy inspection & assessment activities.

“Trust but verify” is a phrase often quoted regarding nuclear safeguards, and the above 4 points serve to illustrate why this is important.

4. SIMRS Development

4.1. Project Start Up – Optioneering and Constraints

All projects are bound by constraints and the understanding of them and the impact they have prior to beginning any optioneering is important to help with sensible down selecting. The political nature of the SIMRS project coupled with an already well-established and complex nuclear industry in the UK provided some considerable, sometimes conflicting, constraints to the project. Whilst the purpose here is not to discuss in detail the origin of the constraints, their inclusion provides useful background for the circumstances of this work and provides context for the decisions taken.

4.1.1. Primary Constraints

The primary constraints associated with the development of SIMRS are listed below:

i. Time – Initial timelines provided less than two years to deliver a working system that would allow ONR to meet domestic and international safeguards reporting obligations;
ii. Severely limited in-house IT capacity and capability – This was primarily driven by an ONR wide IT modernisation project that was ongoing during the SIMRS project;
iii. UK government procurement restraints – IT systems for a UK government project must be procured in compliance with public procurement law, constraining the approaches available to obtain or develop the system in the time available;
iv. Security considerations – SIMRS holds a full inventory of all civil nuclear material in the UK including locations and other sensitive data;
v. The project covers a fully established and wide ranging civil nuclear industry within the UK consisting of ~ 80 Material Balance Areas (MBAs) and 100+ LoFs, covering all aspects of the nuclear fuel cycle including some research and development activities;

vi. Limited existing expert regulatory resources (capacity and capability) in nuclear materials accountancy evaluation;

vii. UK government policy and regulatory restrictions designed to minimise the impact on UK industry – This meant being bound by new domestic regulations that maintained extant Euratom reporting format/schema/inventory change (IC) codes [5]. This placed considerable burden on ONR when considering SIMRS requirements as there was a need for complex translation between two sets of regulatory requirements;

viii. Agreement between UK and IAEA that when correcting nuclear material accounting reports submitted under the UK/IAEA VOA, the VRCP would be used; and

ix. Very limited IT companies with sufficient experience and capability in producing nuclear material accounting software.

4.1.2. Supplier Selection

Early identification of i – iii in Section 4.1.1. above allowed a streamlined tender and down select process to identify and secure IT suppliers with a proven track record in development of both individual operator and State-level NMA systems, producing NMA reports for submission to the IAEA [6], and hosting and support capability within. ONR were ultimately able to secure IT suppliers jointly through, Axis 12 Ltd and its subcontractor, NAC Corporation [7] within UK government procurement guidelines. This process helped mitigate the non-negotiable risk of time and allowed development to start almost immediately after procurement.

4.1.3. Security Considerations

The issue of security of the data was addressed by using UK suppliers of SIMRS, Axis 12 Ltd and its subcontractor, NAC Corporation. SIMRS, and the data contained with it, is classified as UK OFFICIAL – SENSITIVE, placing certain restrictions on who, where and when data can be held and accessed. ONR selected an expert subcontractor who developed the software and the primary contractor to host support and secure data centres in the UK to address export control and data classification concerns. The latter was inspected by ONR cyber security specialists and routine independent penetration tests are performed to provide ONR and the wider UK SSAC assurance on data safekeeping. From a user perspective, access is strictly limited to ONR Safeguards NMA specialists and inspectors using ONR issued hardware.

4.1.4. Understanding Limitations

The scope and scale of the project defined by constraints v – vi in Section 4.1.1. (prior to any system development beginning) highlighted the need to recruit additional subject matter expertise (SME) very early on in the project to provide support to SIMRS and wider aspects of the project. This resulted in ONR gaining additional SME support from the UK nuclear industry, and continuing to work very closely with industry throughout the project

Early engagement with both Euratom and the IAEA on a technical level regarding common nuclear material accountancy issues and the translation and conversion of domestic NMA reports for onwards transmission to the IAEA was also key in seeking to mitigate against vi – viii in Section 4.1.1. by providing a clear understanding of requirements and potential issues from the start of the project.

4.1.5. Stakeholder Engagement

Stakeholder engagement played a key role throughout the entire lifetime of the project. This helped in the very early stages to determine essential requirements of the system and to steer away from issues identified by others. The IAEA provided additional support with testing and validation of SIMRS output, which provided increased confidence before the system went live.

The communications approach for SIMRS focussed on specific key stakeholders (UK government, IAEA, safeguards operators, and ONR safeguards staff) and their interaction with SIMRS. Of particular importance were regular workshops held with industry to provide progress and to help triage areas where SIMRS was posing questions based on live reporting data during testing.

Finally, ONR also reached out to international peers and counterparts during the development of the UK SSAC (including SIMRS) and participated in benchmarking activities with other SRAs to compare the UK's developing SSAC capabilities and gain some assurance that these are in line with international good practice. This work covered engagements with:

- Canada, the Canadian Nuclear Safety Commission (CNSC)
- France, Euratom Technical Committee - France (CTE), Protection and Nuclear Safety Directorate (DSN) of the CEA (French Alternative Energies and Atomic Energy Commission), Institute for Radiological Protection and Nuclear Safety (IRSN)
- Finland – Radiation and Nuclear Safety Authority (STUK)

4.1.6. Waterfall vs Agile – One Size Does Not Fit All

During the lifetime of the project, ONR deployed a hybrid approach to IT development with its suppliers. Variations of both the agile and waterfall methodologies were deployed at different times and for different goals. At the inception of the development the main requirements were clearly understood and outlined. ONR settled upon seven distinct and fully scoped work packages, whilst still allowing iteration and rework, with the first being a discovery phase.

As more bespoke NMA challenges were encountered, we worked closely with operators, suppliers, and the IAEA, adopting a more recognisable agile approach to development. By remaining flexible in our approach to development we were able to make the best use of both subject matter expert and supplier resources to deliver a finished product. This approach was also more prevalent during the 2020 transition period where Euratom continued to regulate the UK allowing ONR to conduct a much longer "Like Live" phase for SIMRS deployment. During this phase UK operators submitted their accounting reports to Euratom and ONR also loaded them into SIMRS concurrently. ONR then assessed the information, translated those reports into IAEA Code 10 format and then agreed with the IAEA to submit a sample of reports to ensure they could be loaded into the IAEA system.

The more traditional Waterfall Model is based upon a software development life cycle that encompasses all the above stages from the Conception to the Deployment in a single plan with a view to delivering a complete product at the end.

In the Agile model, each development cycle encompasses all the phases. Using small, iterative, and incremental developments often where there is a desire to de-risk or where it is not possible to fully define solutions to a problem at the outset.

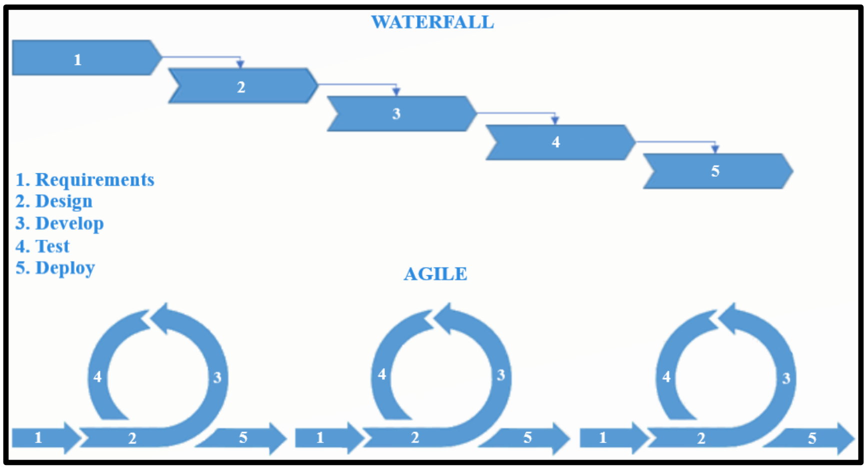

Figure 2. Waterfall vs Agile Comparison

4.1.7. Importance of Requirements

ONR is a nuclear regulator, not an IT developer. As such we had limited in-house available IT expertise during this project (see section 4.1.1,). As with other aspects of this project, ONR acquired through necessity, SMEs in the form of IT test management and business analysts (BA) to work with us and our suppliers and ensure delivery of a quality product.

As with other areas, ONR remained flexible, making sure that we had the right people for any given part of the delivery and changing as the project dictated. However, this was not without lost time and productivity during some stages.

Whilst early development was straightforward with very clear requirements, as the project progressed the level of specificity and detail required increased exponentially to maintain delivery within deadlines and budgetary constraints. Translating the business requirements into deliverable IT/technical requirements was a significant task and required SME BA and tester expertise capable of understanding both the business needs and the software development life cycle (SDLC) whilst being excellent communicators. For the SIMRS project, this was further exacerbated by the limitations placed on us during the COVID 19 pandemic.

4.1.8. Areas of Challenge to SIMRS Development

4.1.8.1. Processing Several Hundred Thousand Items of Data Accurately and Reliably

Whilst the adoption and subsequent adaptation of an "off the shelf" solution provided many benefits; it was not without its limitations. The base code of SIMRS required substantial re-development primarily to handle the volume and complexity of information required for the UK along with the complex translation layer from NSR19 to IAEA Code 10 format reporting.

System performance and reliability was an area that was uncovered primarily through later stage stress testing prior to live deployment and where most of the functionality was already in place. Using an agile approach, the ONR team and suppliers conducted root cause analysis activities and acquired SME resource in specific code optimisation approaches to identify potential problem areas. We then worked iteratively through them by looking at categorising the biggest impact items against the risks of delivery and impact on wider system functionality. This resulted in huge gains in user experience and reduction in processing time whilst maintaining quality outputs. Furthermore, the confidence gained by removing the likelihood of unnecessary downtime against already tight reporting delivery turnaround times requested by the UK/IAEA VOA was invaluable.

4.1.8.2. Traceability Between Two Schemas and Two Correction Principles (BDCP to VRCP)

Constraints identified in 4.1.1. meant that domestically, the UK would maintain its existing MBA structure, MBA codes and inventory change (IC) codes (which were reflected in UK operators' facility nuclear material tracking systems), but it would also have to agree a new set of MBA codes for IAEA reporting under the new UK/IAEA bilateral VOA. Additionally, under the new UK/IAEA bilateral VOA there are no corrections permitted prior to the implementation date of the new VOA, so a technical solution for handling corrections needed to be agreed with the IAEA and a solution found with our IT suppliers.

Whilst these specific circumstances are unlikely to cause problems for other Member States it is included here to demonstrate the importance of early engagement (with the IAEA) in coming to a pragmatic (and in some circumstances bespoke) solution to problems, and in establishing a clear set of requirements, associated use cases and associated testing for the software developers.

SIMRS is capable of automatically performing translation from UK reporting requirements into the IAEA Code 10 reporting requirements, providing essential accountancy transparency for both domestic ONR in-field interventions and IAEA inspectors and NMA specialists.

4.1.8.3. Your System is Only as Good as the Information It Receives

One major challenge that ONR was unable to fully comprehend and understand ahead of the SIMRS project was the variety of nuclear material accounting practices across the UK. With the maturity of the UK nuclear industry and having been through changes in regulation with Euratom since 1973, there was (and continues to be) some legacy practices that meant that building SIMRS purely derived from requirements in NSR19, and IAEA Code 10 was impossible.

A significant portion of SIMRS development consisted of (and continues to consist of) identifying inconsistencies between operators and working with operators to understand the rationale behind their interpretation of nuclear material accounting reporting. This meant that providing a single, catch all set of validations and checks within the system was difficult. This is particularly prevalent in correction chaining and re-batching practices, especially when combined with the translation of information from NSR19 format into IAEA Code 10 format.

To counter this, ONR has adopted a flexible approach to automated completeness and accuracy checking within SIMRS. Implementing an auditable process to all individual automated checks to be turned on and off by ONR NMA specialists and putting more onus on them to perform analysis and checks rather than SIMRS while solutions are sought, and stakeholder engagement continues to seek consistency where possible.

4.1.9. "Perfect is the enemy of the good"

During SIMRS development (especially during testing phases), the ONR team encountered several problems which on the face of them appeared to be very significant (some identified above). With time pressure and a keen desire of the team to have a "perfect" system it was easy to sometimes get lost "down a rabbit hole" focussing on a small part of a potentially bigger issue. Taking the time to look up and evaluate the actual impact/risk/likelihood of a particular problem in real-time operations terms brought many of these concerns back into focus as in reality they were outliers and out of the norm.

As discussed in section 3.2, there will always be exceptions, but where resources are limited (especially time in this case) and mitigations can be deployed, maintaining the focus on delivery of a fit for purpose system covering most requirements for all cases is the key to success. However, comprehensive knowledge and records management to maintain these decisions is essential to ensure nothing is lost and that they can be revisited or justified in the future.

4.2. Testing and Training

The operation and testing of SIMRS was managed systematically to increase complexity and volume over a period of many months. This afforded the opportunity to test ONRs operating procedures, instructions and to examine the system limitations ahead of deployment. Whilst we were against tight deadlines and we were onboarding new staff to build SRA capacity and capability, we took the opportunity to heavily involve the new SRA NMA specialists in testing.

Using ONR NMA specialists increased the testing capacity, but also provided training of staff on the new system ahead of completion. Because both the team and SIMRS were in development simultaneously, we were able to identify early, any issues affecting throughput and workflow and make changes to benefit the team and how they worked immediately.

The inclusion of a "Quality Assurance Manager" to the team further bolstered control, structure and depth of testing and a means to increase resilience through clearly defined testing strategies and training for the wider team. QA and testing even though used interchangeably are quite different roles. ONR plugged the QA gap, therefore allowing better insight and transparency into what the suppliers deliver. Naturally, this has reinforced ONR's capability but primarily it has brought the suppliers capability into sharp focus.

Finally, the assistance offered by the IAEA in the months running up to deployment to allow ONR to submit declarations through the IAEA State Declarations Portal (SDP) and to validate and analyse the accuracy of submissions was vital, not only allowing us to correct some minor issues but in demonstrating a clear ability to move from project to deployment to UK Government and the rest of the UK SSAC.

5. Future Development Opportunities

Following project close out and successful transition into its role as UK SRA, ONR continues to work closely with ONR NMA specialists, the IAEA, UK industry and other stakeholders to examine and assess and improve the functionality and capability of SIMRS. Any areas for improvement identified following these interactions are being reviewed for incorporation into future releases of the software.

Some of these include items that were initially recognised during discovery as desirable but de-scoped due to time or other considerations discussed in this document, along with further items following 18 months of use by ONR NMA specialists.

Of note are the following areas currently considered for future development:

- Increased analysis and trending functionality that is further integrated with other ONR business logic, processes, and analytics.

- Expanded functionality regarding UK international nuclear cooperation agreements (NCA) – including the use of XML for notifications.
- Streamlined reporting functionality for LoFs who carry limited quantities qualifying nuclear material.

6. Conclusions

Since the UK provided notice of its decision to leave Euratom at the end of March 2019, ONR (funded by UK government) has successfully procured, developed, and deployed nuclear material accountancy software to support ONR as the SRA for the newly formed UK SSAC. ONR cooperated closely and worked collaboratively with the UK civil nuclear industry, international partners, and the IAEA to develop SIMRS as a unique solution to meet both domestic UK and international nuclear safeguards commitments.

Since beginning live operations as the UK SRA in January 2021, ONR continues to receive positive feedback from the IAEA providing assurance that not only did the SIMRS project clearly deliver its key international delivery goals against considerable challenges, but that the UK continues to meet our VOA commitments month on month.

7. Acknowledgments

The authors would like to acknowledge the efforts and dedication to the SIMRS project over several years by the entire ONR development team, but in particular, Dr Mike Beaman (UK Safeguards SME), Dr Alan Homer (UK Safeguards SME), Mr Luke Harrop (AXIS 12 Ltd), Mr Dan Collier (NAC International), Mr Sam Brown (NAC International), Ms Francine Gradie (Business Analyst), Mr Alain Rialhe (Safeguards SME contractor), Mr Greg Hawes (IT procurement, contracts and supplier management specialist), Mr Majid Khan (QA Manager), Mr Evan Crawford (IAEA) and Mr Tomas Stepanek (IAEA).

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