Project 'MERCURY'

Embracing Digital Twins Lifecycle Management for Complex Weapons

TD-Info Digital Twin Community of Practice
(Asset Tracking Team)

Project 'Mercury' clearly and powerfully illustrates the potential of applying a Digital Twin approach to Complex Weapons, delivering annual savings of £31-42 million in the Air domain alone, with a further £21-28 million achievable across Maritime and Land. It also reduces the time spent on repetitive manual record-keeping and reporting by 30%, equivalent to an annual productivity saving of £2 million.

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Ministry of Defence

TEAM DEFENCE INFORMATION

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1. Executive Summary

Context and Strategic Alignment

The Team Defence Information (TD-Info) Digital Twin Community of Practice has, through extensive collaboration with MOD stakeholders and industry partners, reached a pivotal point in the journey to transform Complex Weapons (CW) lifecycle management. The findings of the Discovery Phase clearly demonstrate alignment with the MOD's strategic priorities, including the new National Armaments Director (NAD) mandate to reform Defence procurement, accelerate capability delivery, and strengthen industrial partnerships.

This initiative sits at the heart of MOD's digital backbone and directly supports strategic outcomes of delivering capability faster, more efficiently, and with greater transparency. By aligning with the ongoing Munition Lifetime Extension (MuLE) programme on general munitions, this project capitalises on proven thinking and ensures scalability from general munitions to CWs. It represents a unique opportunity to establish a Defence-wide blueprint for digital asset lifecycle management.

Financial and Productivity Gains

Project 'MERCURY' embodies a compelling financial case, delivering measurable cost savings while enhancing the flow of critical information across Defence. Named after the Roman God of communication and financial gain, the project symbolises a dual promise: operational effectiveness and prudent stewardship of public resources. Risk-averse assumptions currently lead to premature disposal of CWs, driving avoidable procurement and sustainment costs. By digitising lifecycle management, we estimate annual savings of **£31-42 million** in the Air domain alone, with a further **£21-28 million** achievable across Maritime and Land. Over a 5-10 year horizon, these savings equate to hundreds of millions of pounds in avoidable expenditure. Alongside financial benefits, productivity gains are equally significant. Across four major Explosive Storage Areas (ESA), approximately 150 RAF armourers are engaged in CW management, with 30% of their time consumed by repetitive manual record-keeping and reporting. This equates to an annual productivity cost of around **£2 million**. Automation of these tasks will free skilled personnel to focus on mission-critical activity, improving both morale and retention, as well as overall battle readiness.

Data-Driven Transformation

Perhaps the most transformative aspect lies in the data. Section 6 of the main report demonstrates how automated data capture and digital reporting will provide senior stakeholders with unprecedented visibility of weapon condition, location, and availability. Access to trusted, real-time data will allow evidence-based decision making, improved forecasting, and faster operational readiness. Over time, this dataset will generate unforeseen benefits across manufacturing, sustainment, and wargaming – a true foundation for future Defence innovation.

This approach supports not only current readiness but also long-term strategic resilience. It reduces reliance on risk-averse assumptions, ensuring that every CW delivers its full operational potential while maximising taxpayer value.

Technology and Proven Solutions

Our proposal is grounded in technologies already proven in Defence. Babcock's SharpCloud platform is delivering today at SECRET classification in support of the submarine enterprise. Convert Technologies' MuLE Tags are already developed and trialled in partnership with BAE Systems on general munitions, providing accurate environmental and location data. Together, these provide a secure, resilient, and scalable architecture for CW management.

The Discovery Phase has validated feasibility and scoped options, while a demonstration planned for end of Q1 2026, will allow senior stakeholders to visualise the system in action. This demonstration represents a vital milestone to build confidence and accelerate sign-off.

Stakeholder Readiness and Momentum

One of the strongest indicators of success has been the enthusiasm of front-line RAF armament teams, who see immediate value in reducing their manual burden. Coal-face acceptance of this nature is limited within MOD programmes and provides a solid foundation for wider adoption. Substantial work has already been invested (253 man-days) by the Discovery Team to reach this point, underlining both momentum and commitment. This initiative aligns directly with MOD Capability Centres and sits at the core of the strategic imperative to 'do stuff faster'. It also supports wider MOD strategic outcomes, including improved platform availability, through-life asset management, and reduced material waste.

Strategic Imperative – Seizing the Opportunity

The cost of doing nothing is high. Current manual processes erode capability, drive unnecessary procurement, and place unsustainable burdens on highly trained personnel. Without change, Defence risks missing a once-in-a-generation opportunity to modernise weapons management.

The choice is clear: continue with inefficient legacy systems or seize this moment to grasp the nettle and deliver a transformative solution. The proposed Digital Twin approach is low-risk, high-return, and entirely consistent with MOD strategic direction. It provides an evidence-based blueprint that can be extended beyond the RAF to Maritime, Land, and other asset classes. We believe the case is compelling. This initiative delivers measurable financial savings, unlocks productivity, enhances readiness, and ensures Defence is prepared for the challenges of tomorrow. The time to act is now.

2. Introduction

2.1 Purpose of This Paper and Definition Setting

TD-Info is a collaborative association that informs Defence information policy and pilots new ways of working. TD-Info's Digital Twin workstream has been active since 2019, has attracted 650+ members, and has explored the introduction of a synthetic environment to support frictionless access of data at appropriate authorisation. The ideal future solution is an ecosystem of Digital Twins across the entire Defence enterprise which enable timely and useful decision, design, and capability support.

This is the fourth iteration White Paper output of the TD-Info Digital Twin Community of Practice and an illustration of previous investigations being developed further: Section 5 of the third White Paper recounts a visit to MOD Aberporth Range, where the challenges around Test and Evaluation (T&E) of Aircraft stores was made apparent. As evidenced within the completed investigation, this task has been created as a direct result of sponsorship from relevant and appropriate MOD responsible owners and subject matter experts (Commands, Dstl, DE&S) and its findings continue the journey to demonstrate practical Digital Twin solutions.

Reference: Link to Third White Paper

What is a Digital Twin?

The phrase Digital Twin can hold many varying meanings depending on the industry and the purpose required. It is therefore important to define specifically what is meant by Digital Twin in the context of the proposed tasks.

"A Digital Twin is a connected data representation of an entity, such as a physical asset, a process or system throughout its lifecycle." (As defined by the first 'Digital Twin for Defence Engineering Support' White Paper – September 2019).

Overarching definitions in this setting (can be an asset, product, service, or enterprise) in most circumstances can be a mix or amalgamation of all these:

- Digital Twin – Connected both ways from 'real' to Digital.
- Digital Model – Not connected to 'real.'
- Digital Shadow – Connected one way from 'real' to Digital.

To summarise, a Digital Twin is best described as a visualisation and scenario builder to assist with decision making.

Project Context and Anticipated Outcomes

The field of Digital Twins holds incredible possibilities within the entire Defence landscape. Project MERCURY was conducted and greatly enabled using the MOD RDT&E funded 'Zeus' concept. This incentivises a collaborative approach between small medium enterprises (SMEs) and major Defence companies yielding Defence value and gains beyond individual projects. The Zeus approach provides for a transferable blueprint for future Defence enterprise working which is modular, agile, repeatable and scalable.

This teamwork is dynamic, and the collaboration provides for successful and more rounded outcomes than relying on the efforts of solo actors.

What did industry facilitate and how did they support this task for MOD?

This paper is the culmination of collaboration between TD-Info and a voluntary Team of Industry experts from Convert Technologies and Babcock. The paper seeks to articulate the problems currently faced by Commands and MOD with CWs asset management. Countermeasures/Flares was the original focus of the project, but after engagement with RAF Armoury teams, the Asset Tracking Team agreed to make the primary focus for Digital Twin assessment CWs, due to the greater impact and potential savings that could be achieved.

This wider focus delivers a dual benefit: improvements made to CWs lifecycle management inherently enhance the management of Countermeasures/Flares, given the shared logistical, environmental, and through-life considerations. By adopting a holistic approach, we can identify solutions that are scalable across the CW family first before the specialist requirements of Countermeasures/Flares can be fully addressed as a further phase.

The industry experts' involvement and their valued contribution enabled them to obtain a privileged understanding and direction of travel from within Defence and then shape, influence and assist towards CWs development. There was also the opportunity to work as part of a team with equally capable and knowledgeable organisations within Defence and the wider digital community.

This paper seeks to support the commissioning of a more digital approach to asset management by accelerating the procurement process. The objective is to deliver a safe, fit-for-purpose solution for CWs that is achieved 'right first time' and designed to meet future requirements.

This will include:

- Understanding how focus areas will federate and interact to realise a future end state.
- Articulation of requirements for Federated Digital Twinning capability across the enterprise.
- Development of capability roadmaps.
- Alignment, pull through and learning from representative Digital Twining capabilities.
- Assessment of potential system solutions and recommendations for capability development.

What is an Aircraft Complex Weapon?

In Military and Defence contexts, a CW refers to a sophisticated, high-precision weapon system that relies on guidance systems to achieve accurate and targeted effects. These weapons are often characterised by their reliance on advanced technology, such as GPS or Laser Guidance to ensure they hit their intended targets with minimal collateral

damage. CWs can serve in both strategic roles (long-range attacks) and tactical roles (close-air support, air defence), categorised by their target type and deployment.

What is an Aircraft Flare?

In the case of Aircraft Countermeasures – specifically flares – the ability for them to provide a decoy is a well-established concept and has been in service in the RAF since the 1960s with the Vulcan bomber. Not only is it relevant for today as a Countermeasure, but it will also be relevant for the foreseeable future. An aircraft Countermeasure flare is a pyrotechnic device used to defend against infrared-guided missiles. These flares are designed to burn much hotter than an aircraft's engine exhaust, acting as a decoy to lure the missile away from the aircraft. They are a key component of an aircraft's self defence system.

Scope of Analysis

Target Audience

This paper is intended primarily for the MOD's strategic and operational stakeholders who have both the remit and influence to implement meaningful change:

- **Primary MOD sponsors** – RAF, MOD Defence Equipment and Support (DE&S), and Defence Science and Technology Laboratory (Dstl), who initiated this area of investigation to gain an independent, industry-informed perspective on potential improvements.
- **Director of Strategic Programmes and RAF senior leadership**, whose decision-making authority and operational oversight can translate recommendations into actionable policy and practice.
- **Forthcoming National Armaments Director (NAD)** – a newly established, four-star role within the UK MOD, tasked with reforming Defence procurement, strengthening the industrial base, and ensuring supply chain resilience. The timing of this work aligns closely with the NAD's mandate, offering evidence-based insights that can inform strategy from the outset.
- **Consistent with the two preceding Digital Twin White Papers** - Project MERCURY is currently issued without a formal security classification.

Strategic Timing and Relevance

The expansion of this study's scope coincides with a critical juncture in UK Defence procurement reform**.** The creation of the NAD role represents a deliberate shift towards faster, more integrated capability delivery, underpinned by strong industry partnerships and data-driven asset management.

Our findings and proposed solutions directly support these objectives, offering:

- **Operational efficiency gains** through accurate, data-led Shelf-Life management of CWs.
- **Resilience in the supply chain** by extending usable life and reducing premature withdrawal of CWs.

- **Enhanced readiness** through better integration of environmental, handling, and usage data into asset management systems.

By addressing CWs holistically and applying those insights to subsystems like flares, the MOD can achieve both near-term readiness improvements and long-term sustainment benefits.

Key aspects of the new MOD NAD role:

- **Addressing inefficiencies:** The NAD is intended to tackle issues within the MOD's procurement system.
- **Ensuring adequate equipment:** A primary goal is to ensure the UK armed forces are properly equipped to meet current and future threats.
- **Boosting the Defence industry:** The NAD will play a role in building up the UK Defence Industry and supporting exports.
- **Accountability:** The NAD will be accountable to the Defence Secretary.
- **Collaboration:** The role will require close collaboration with various stakeholders, including government departments, industry, academia, and international partners.
- **Focus on value for money:** The NAD will be tasked with delivering better value for money for taxpayers and improved outcomes for the armed force.

2.2 The Discovery Phase

Origins and Evolution of the Asset Tracking Task

The Digital Twin Programme's Asset Tracking Task began in February 2024 with an initial focus on aircraft Countermeasures and flares. Under the leadership of Ian Grostate, and following discussions with Darin Tudor, the task was launched to explore how digital solutions could transform asset management. Ian's prior experience leading Project MuLE with BAE Systems positioned him ideally to drive this effort, given the parallels in technology and operational requirements.

In the early months, the team engaged with Chemring, a leading manufacturer of Countermeasures, and one of the Task Sponsors, Stephen Searles, who manages the RAF's Countermeasures portfolio within Defence Equipment and Support (DE&S). These early engagements highlighted the potential benefits of digitisation but also revealed the significant complexity and inefficiency inherent in current manual processes.

A visit to RAF Odiham in October 2024 provided critical first-hand insight. Discussions with Corporal Luke Head and his team highlighted the labour-intensive nature of managing Countermeasures, with large amounts of time consumed updating paperwork and multiple data repositories. It was here that the team began to understand the scale of opportunity for improvement. Corporal Head recommended extending the scope to RAF Marham's 93 Squadron, whose armament teams manage a much wider and more complex range of assets, including CWs, a suggestion that proved pivotal to the potential impact of this work.

In March 2025, the Asset Tracking Team visited RAF Marham, and met with Flying Officer Mitchell Collins, and Chief Technician Alec Hunt. During preparatory discussions, Alec Hunt emphasised that Countermeasures represented only around 15% of his team's workload, whereas CWs consumed the remaining 85%. It became immediately clear that focusing on CWs would deliver the greatest financial and operational impact. The visit confirmed this, with detailed input from Squadron personnel, and led to the recommendation that CWs become the primary focus of the Digital Twin initiative, with Countermeasures to follow as a secondary phase.

A subsequent visit to RAF Marham in June 2025 reinforced this conclusion. Alec Hunt and Mitchell Collins, supported by senior and junior NCOs, provided in-depth process walkthroughs, which have informed the Process Flows in Section 4 and the Impact Analysis in Section 6 of this paper.

Over the past nine months, it has also become clear that various activities across Defence, such as review investigations from Babcock, have begun exploring elements of weapon life-extension and digital tracking. However, these efforts have been fragmented, pursued in isolation, and without a unifying framework. This White Paper (Project MERCURY) aims to address that gap by presenting a coordinated vision.

Specifically, it sets out:

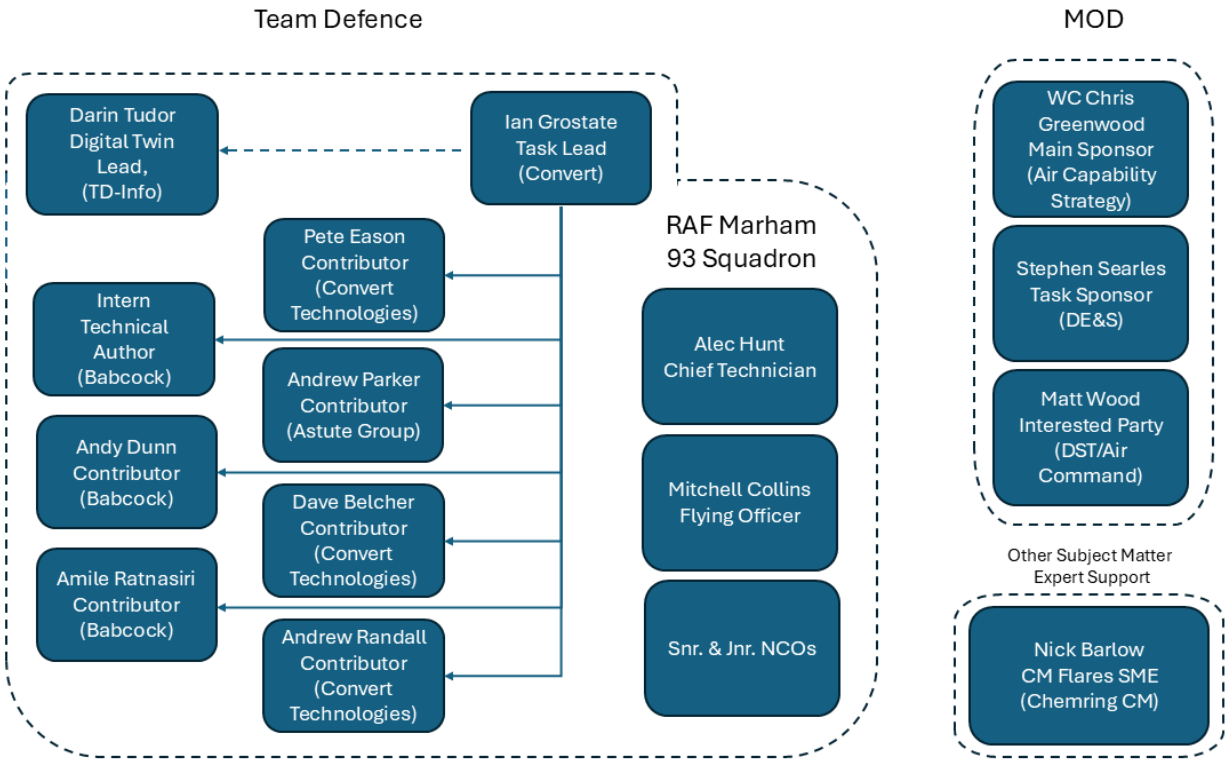
- **A strategic vision** for a unified digital solution for CW lifecycle management.
- **A financial case**, estimating annual cost savings achievable through implementation.
- **Operational benefits**, including improved workforce efficiency, reduced staff turnover, and increased lethality.
- **A delivery roadmap** designed to secure senior stakeholder support and sponsorship.
- **A scalable template**, capable of extending to the Maritime, Land, and other equipment classes requiring lifetime management.

By consolidating these threads into a single, coherent approach, the Asset Tracking Task provides not only a technical solution, but a strategic opportunity for Defence to modernise, save costs, and unlock new levels of operational assurance.

It is worth noting from inception to get to this position of presenting this White Paper has taken 253-man days of work by the Asset Tracking Team.

2.3 Organisational Overview

The Digital Twin Community of Practice, Asset Tracking Team personnel are as follows:



3. Context and Background

3.1 Historical and Sectoral Context

As part of the Discovery phase of the Digital Twin study, a review was conducted of the CWs operationally held at RAF Marham. This review included an assessment of financial costs and existing Government contracts in place to deliver and sustain these CWs for the MOD.

It is important to note that this analysis did not encompass the full spectrum of CWs in service with the MOD. However, it is highly likely that the challenges identified at RAF Marham - such as manual record-keeping, fragmented processes, and conservative risk-averse lifing assessments, are being replicated across other weapon types and locations.

Therefore, any future phases of a digitisation programme for CW handling and reporting should extend the scope beyond RAF Marham to cover the wider CW inventory. Doing so would support the MOD's broader vision of enabling all CWs to be monitored through a single, integrated digital system - one that provides accurate ageing profiles, location data, and lifecycle status in real time.

By achieving this level of visibility, the MOD could significantly reduce costs, minimise waste, reduce highly skilled staff turnover, and provide all relevant stakeholders with a trusted, evidence-based picture of asset readiness.

The evolving shape of modern warfare is driving changes in the cost structures and volumes of CWs. Increasingly, CWs are expected to converge with general munitions, creating substantially higher demand across all categories of weapon. Project MERCURY anticipates this trajectory, offering a scalable, umbrella solution (see Section 5) capable of managing the entire spectrum of weapons. This positions the initiative as not only valuable today but also essential to future weapons development and sustainment.

Complex Weapons Covered by the Digital Twin Asset Tracking Task

Within the scope of the Digital Twin study, two principal manufacturers were identified as the providers of the CWs stored at RAF Marham. While the majority of missile development and sustainment contracts are delivered through industry consortia, the primary contractors in this case are MBDA and Raytheon.

Both companies supply a range of advanced CWs to the UK, each with distinct operational roles, service entry timelines, and sustainment requirements. These CWs formed the focus of the study, providing representative insights into the broader challenges of lifecycle management across the UK's CW inventory.

MBDA

- **ASRAAM** (Advanced Short-Range Air-to-Air Missile).
    - **Role:** Short-range air-to-air missile, infrared homing with imaging sensor.
    - **In service since:** 1998 with the RAF.

  - **Notes:** High agility and speed for close-in engagements; carried by Typhoon and F-35B.

- **Brimstone** (Air-to-ground Missile).
  - **Role:** Highly accurate ground-attack missile, millimetric wave radar and semi-active laser guidance.
  - **In service since:** 2005 (single-mode); 2008 (dual-mode).
  - **Notes:** Optimised for moving and armoured targets; integrated on fast jets, helicopters, and UAVs.

- **Meteor** (Beyond-Visual-Range Air-to-Air Missile).
  - **Role:** Long-range air combat missile with ramjet propulsion for sustained high speed.
  - **In service since:** UK operational integration from 2018.
  - **Notes:** Provides no-escape zone advantage; equips Typhoon and F-35B.

- **Storm Shadow** (Air-Launched Cruise Missile).
  - **Role:** Long-range, conventionally armed, stealthy cruise missile for deep strike.
  - **In service since:** 2004.
  - **Notes:** UK–French programme; BROACH warhead; combat-proven in Iraq, Libya, and Syria.

Raytheon

- **AMRAAM (AIM-120)** (Advanced Medium-Range Air-to-Air Missile).
  - **Role:** Beyond-visual-range air-to-air missile using active radar homing for all-weather intercepts.
  - **In service since:** UK adoption from the 1990s (AIM-120 variants have been in UK service since the 1990s and later upgrades/variants continued in service).
  - **Notes:** US-designed and produced by Raytheon (now RTX); adopted by the RAF as an interim BVRAAM solution and integrated on Typhoon among other platforms.

- **Paveway IV** (Precision-Guided Bomb).
  - **Role:** Air-to-surface precision-guided munition, GPS/INS guidance with semi-active laser terminal guidance for high accuracy.
  - **In service since:** 2008 with the RAF.
  - **Notes:** Developed and produced by Raytheon UK; cleared for Typhoon and F-35B employment and used extensively on operations.

Budget Allocations: Production and Maintenance of Complex Weapons

Within the scope of the Asset Tracking Task, it has not been possible to isolate the annual spend or contract values specific to the CWs held at RAF Marham. This is due to the way costs are structured within wider commercial agreements, often spanning multiple years, delivered through industry consortia, and covering commitments to multiple nations.

As a result, expenditure data is embedded within broader Defence contracts rather than attributed directly to individual CW inventories at a single location. The following sections therefore present the available contractual and spend information at a higher level, reflecting the aggregated nature of procurement and support arrangements.

MBDA Partnership (PMA2)

- Investment: At least **£6.5 billion** over the next decade (From 2024) for CW systems. **Reference:** Defence Equipment & SupportMBDA Newsroom.
- This confirms MBDA as UK MOD's preferred supplier of CWs.

Raytheon Contracts

AMRAAM

Procurement/notable contracts: AMRAAM production is managed by Raytheon in lots awarded by the US DoD; recent large production contracts (multi-hundred-million to multi-billion USD) routinely include Foreign Military Sales (FMS) lots for allied purchasers - recent large tranche awards in 2024-25 (including a reported $3.5bn award in 2025) list allied buyers such as the UK among the potential FMS recipients. The US Selected Acquisition Report and Lot contract documents show specific Lot quantities and FMS allocations in the hundreds per Lot.

Known UK quantities and procurement route: the UK has procured AMRAAM variants historically (1990s onward) and is routinely listed among nations eligible to buy AIM-120D via FMS; exact UK Lot-by-Lot quantities are not always published in MOD GMPP rows. Public SAR/Lot docs show FMS-labelled missiles in Lot deliveries (e.g. Lot 32 included 225 FMS AIM-120C-7 missiles across buyers), which demonstrates how the UK receives missiles via multi-nation Lots rather than discrete UK-only production contracts.

Approximate unit price: US production/contract signals and historic FMS packages imply an order-of-magnitude ~$0.8-1.2 million per missile (varies by variant, lot, spares, telemetry, and package). Converting to GBP depends on exchange rate; do not treat as a definitive UK invoiced unit price.

Production/year notes: AMRAAM is produced in US production lots (e.g., Lot 31/32 in 2019-2021). Lot deliveries often span multiple calendar years; FMS allocations to the UK occur inside those Lots, so attributing a single UK FY production figure requires Lot-level FMS allocation data (not always public). Recent DoD awards (2024-25) increased overall AMRAAM production capacity, and multi-billion dollar contracts indicate large multi-year output levels available to allies including the UK.

Confidence/caveat: Medium-low. Unit-price and Lot allocation signals are public, but the UK's exact per-Lot quantities and per-FY production receipts are not published in MOD GMPP, so precise UK figures require FMS case data or MOD disclosure.

Reference: Defense Logistics Agency

Paveway IV

Procurement/notable contracts: Raytheon UK production at Glenrothes has been sustained by UK and export contracts; a widely reported export contract to Saudi Arabia was ~£150 million for ~2,400 Paveway IVs (reported in trade/industry coverage). Raytheon/US DoD contracting notices also show US-side Paveway Family Production/TPA contract activity (multi-hundred-million-dollar contract ceilings used for production, sustainment and integration).

Approximate unit price (derived): £150,000,000 ÷ 2,400 = £62,500 per weapon (this matches public reporting which commonly cites ~£60–70k per Paveway IV in those contract announcements).

Production/year notes: production was active through the 2010s to support RAF use and the Saudi export; Raytheon reported milestone deliveries (industry reporting references the 4,000th Paveway IV delivery around the mid-2010s). US contract modifications in 2019 increased production/TPA ceilings for the family, indicating ongoing multi-year production lines. Exact UK-FY-by-FY production volumes are not published in GMPP (commercially sensitive).

Confidence/caveat: Medium. The £150m/2,400 figure is from public trade reporting (Think Defence) summarising contract data; firm GMPP whole-life or FY split numbers for Paveway IV are not published.

Reference: Think Defence

3.2 Stakeholder Map

3.3 Stakeholder Overview

Stakeholder	Role	Responsibility	Relevance to Digital Twin Solution
National Armaments Director (NAD)	Strategic Defence Leadership	Oversees national armaments policy and NATO alignment	Provides top-level endorsement; ensures interoperability of Digital Twin adoption across allied frameworks
RDT&E (Research, Development, Test and Evaluation)	Science, Testing and Evaluation	Develops, trials, and certifies Defence technologies	Validates Digital Twin models and simulations, enabling trusted virtual trials and assurance
Director of Strategic Programmes	Strategic Capability Oversight	Leads major programmes including CWs and nuclear	Key influencer: ensures Digital Twin is embedded into long-term strategic capability delivery
RAF HQ Specialist Support	Centralised Operational Support	Provides technical support and standardisation for frontline units	Ensures consistent CW lifing and handling processes across RAF bases through digitisation

Stakeholder	Role	Responsibility	Relevance to Digital Twin Solution
Defence Science and Technology Laboratory (Dstl)	Science and Technology Authority	Provides impartial technical expertise and innovation	Validates data integrity and modelling; adds scientific credibility to CW Shelf-Life extension. Originators of the Digital Twin initiative
Weapon Information and Support Management (WISM)	Data and Reporting Hub	Coordinates CW data, reporting, and compliance	Reduces manual reporting burden; enables automated, secure data flow within MOD
Delivery Teams / Defence Equipment and Support (DTs/DE&S)	Acquisition and Lifecycle Management	Procures, supports, and sustains MOD equipment	Aligns with DE&S 2025 digital goals; improves efficiency, reduces costs, and accelerates capability delivery
RAF Marham, 93 Squadron Armourers Team	Frontline CW Management	Handles daily CW preparation, reporting, and lifing	Direct beneficiaries of automation; reduces manual workload, improves accuracy, enhances readiness
Complex Weapons Manufacturers (MBDA, Raytheon, etc.)	Industrial Partners	Design, manufacture, and support CWs	Collaborate on accurate, data-driven lifing assessments; reduce unnecessary penalties while ensuring safety

4. Current Processes for Monitoring and Storing CWs

4.1 Evaluation of Current Procedures: Summary and Weaknesses

The current management and reporting of in-service CWs across their operational lifecycle remains a heavily manual and fragmented process. This approach is not only resource-intensive but also prone to human error and procedural inconsistencies, resulting in inefficiencies that ripple across multiple teams responsible for Shelf-Life Expiry Date (SLED) management.

Within RAF armament units, the manual capture and recording of basic health and usage data consumes around 30% of total working time. This repetitive administrative burden increases operational pressure on highly skilled personnel, driving higher staff turnover and further eroding productivity.

In addition, some of the very actions required to report on lifing metrics can inadvertently shorten a CW's SLED by triggering lifing penalties, ultimately reducing usable stock availability.

A culture of necessary caution, driven by the absence of precise environmental and usage data leads to conservative, assumption-based SLED assessments. While this approach mitigates risk, it also shortens weapon life unnecessarily. With the unit cost of some CWs approaching £2 million, this practice results in significant over-procurement to maintain operational readiness, placing avoidable pressure on MOD budgets.

4.2 Workflow of Existing Procedures and Tools

At RAF Marham, the end-to-end handling of CWs, from receipt through to onward deployment involves multiple handovers and information exchanges between Delivery Teams (DTs), Weapons In-Service Management (WISM), CW Manufacturers, and RAF armoury personnel. Each additional interface increases complexity, delays, and the potential for data discrepancies, negatively impacting overall productivity and operational efficiency.

This combination of manual processes, conservative lifing assumptions and fragmented communication not only reduces the effective availability of high-value assets but also represents a strategic opportunity: to modernise CW lifecycle management with digitally enabled, evidence-based, and automation-driven solutions that both extend usable life and optimise budget expenditure.

Main Supporting Tools of the Current Process

JSMCR - Joint Services Munitions Control Register: A Manual, Risk-Averse Bottleneck

The JSMCR is a centrally accessed Excel-based information store on MoDNet, used by key stakeholders including RAF armament teams, DTs, and the WISM to record and update a CW's SLED throughout its operational life.

For CWs such as AMRAAM and ASRAAM, the SLED limits associated with different Aircraft Carriage Hours (ACH), transport carriage hours, and operational activities are documented upon production release. Updating these records, however, is far from straightforward. Each update requires a complex assessment of multiple factors from handling and storage history to environmental exposure and demands manual input and interpretation from all parties involved as the CW progresses through its service life.

This process is both time-consuming and error-prone, placing a heavy administrative burden on armament teams. The reliance on interpreting historical data, coupled with the lack of automated precision, means that assessments are typically made from a risk-averse standpoint leading to a consistent underestimation of actual CW life.

The result is a systemic reduction in usable asset availability, driving avoidable procurement and reducing operational efficiency issues that could be mitigated through automated, data-driven SLED management.

Complex Weapons - JSMCR Entries (Examples of unstructured and unformatted data)

AMRAAM

Storage life = 5.0 years from the date of Explosive Dish Assembly. Road Transport = 20,100 Km by road. Sea Transport = 90 days by RFA or Merchant Ship. Up to 3 years embarked on Queen Elizabeth Class Carrier. Airfield Transport = Transport on lightweight trailers including S-Type trailers, up to 400 Km (In All Up Round Container Only). Forklift = Transport on forklift and loading trolleys (In AUR container only), up to 120 Km. Air Transport = 32 hours air transport in C17, No A400 air carriage can be supported at this time. LII F-35B Stations 4, 5, 7 & 8 = 50 ACH and a lifetime maximum of 55 door cycles (Should an AIM-120D be exposed to over 55 WBD cycles, it should be removed from the aircraft, quarantined within its container and AAM DT advice should be sought). Service Life of the AIM 120D missile is to be reduced at a rate of 2.125 days per ACH flown on F-35B. Gunfire = No Gunfire Permitted.

ASRAAM

Service Life. The ASRAAM Blk 6 OM is limited to 10 years' Service Life from Rocket Motor Fill Date. Air Transport. The ASRAAM Blk 6 OM is limited to 300 hours (internal) C-17; 100 hours (internal) C-130J and 50 hours A400M (Ramp-Only Clearance). Note: hours accrued on A400M must also be recorded against C130J limit. The ASRAAM BLK 6 OM is currently NOT cleared for transport as an Underslung Load. Road Transport. The ASRAAM Blk 6 OM is limited to 45,000km Road Transport; 5000km Off-Road/Degraded Road; 580km Lightweight Trailer (inc. S-Type); 320km Forklift/Trolley transport; and 45,000km Rail (Not as Loose Trolley). Sea Transport. The ASRAAM Blk 6 OM is limited to 5-years Sea Transport on RFA/RO-RO. It is currently not cleared for embarkation on QEC. Exposure Life (Standby). The ASRAAM Blk 6 OM is limited to 224 days A1, A2 and Marine Climatic Categories and 550 Exposure Days in A3. It therefore accrues Standby Life at a rate that is subject to the climatic category environment that the missile is exposed to (e.g. 1 day in A1, A2 or Marine Climatic Categories = 2.5 days equiv in A3). The ASRAAM Block 6 2(R)1

should be referred to for further guidance. Replenishment at Sea. The ASRAAM Blk 6 OM is currently NOT cleared for RAS (either by JACKSTAY or VERTREP).

Equipment Record Card (ERC): A Paper-Based Legacy System

The ERC also referred to as the *714 Logbook*, is a hard-copy document stored with each CW inside its Specialist-to-Type Container (STC)**.** The ERC contains the full historical record of the CW's movements, storage conditions, maintenance activities, and modifications throughout its service life. To read or update the ERC, requires opening the STC. This gains a penalty of one exposure day, to the SLED.

Upon receipt of a CW, RAF armament teams manually review both the ERC and the JSMCR to reassess the SLED considering recent activities. However, there is no standardised format for ERCs across CW types, leading to inconsistencies in the way information is recorded and interpreted.

As CWs circulate between RAF bases over the years, their ERCs grow in length and complexity. Reviewing these records is a time-intensive process, reliant on the individual experience and judgement of the armament personnel. This subjectivity can result in disagreements or uncertainty, often requiring further consultation with DTs. Such discussions frequently lead to penalty lifing decisions, which shorten the SLED and must then be recorded in the JSMCR.

On the rare occasion a CW arrives without its accompanying ERC, a Munition Incident Report D (MIRD) is raised and reported to the DTs, who investigate the incident to determine whether it is an isolated case or part of a wider issue, with DTs advising on the appropriate course of action for the CW involved.

This reliance on manual, paper-based records introduce unnecessary delays, increases the risk of error, and often leads to conservative SLED reductions. Transitioning to a digital, standardised, and centralised record system would greatly enhance accuracy, speed, and confidence in lifecycle assessments, while reducing the administrative burden on skilled personnel.

Daily Flight Reports

On-Base CW Movements: Penalties, Manual Reporting, and Error Risk

Daily Flight Reports are maintained by Squadrons, with data reported back to 93 Squadron, which maintains the CWs' ERC.

Even the routine movement of a CW within RAF Marham for example, transferring it from station storage to a squadron can shorten its SLED. Preparation takes place in a temperature and humidity-controlled area, yet the mere act of readying the CW for deployment triggers a reduction in SLED.

CWs are then transported on slow-moving carriers, with '*trundle distance'* recorded as part of their handling history. Upon receipt, squadron armourers assume responsibility

for both CW handling and the recording of flying hours, the single greatest factor in SLED reduction.

This data is collected via Daily Flight Reports (DFRs), derived from the aircraft's Electronic Support System (ESS), and then manually reported by email to 93 Squadron including 'nil returns' when no relevant activity has occurred. The manual nature of this process, combined with multiple data handovers, introduces significant opportunity for human error.

Once collated, 93 Squadron provides a weekly consolidated report to WISM. At this stage, personnel can flag CWs with ORANGE or RED status based on High Aircraft Carriage Hours (HACH), signalling urgent attention or priority action.

The process of moving munitions from ESA to prep areas, or to ESH for use by squadrons, and vice versa, incur multiple manual touch points. For example:

- Transport vibration and temperature variations.
- Fork-lifting to and from transport to stores.
- Transport to aircraft for flight.
- Flight duration and door opening.

As data is not automated, the impact on asset life is estimated by applying the lifing metrics detailed in the JSMCR. The manual recording of data which is estimated, erodes asset life unnecessarily and increases the likelihood of errors in critical decision-making. Implementing automated data capture and integrated reporting would maximise CW SLED.

MJDI: Inventory Control in the NATO Codification Framework

The Management of the Joint Deployed Inventory (MJDI) has recently been introduced across all UK Armed Forces as part of the wider NATO codification system, the framework responsible for managing the inventory of all service equipment, including CWs.

When 93 Squadron deploys overseas, Squadron Logistics personnel use MJDI to coordinate the allocation of all required equipment, tools, general supplies, and CWs to the deploying armament team. For CW-specific requirements, MJDI provides the formal stores allocation command, ensuring coordination between the WISM and the appropriate supply chain personnel.

While MJDI ensures standardised inventory visibility and aligns with NATO best practice, its current use in CW management remains focused on logistical allocation rather than through-life condition tracking.

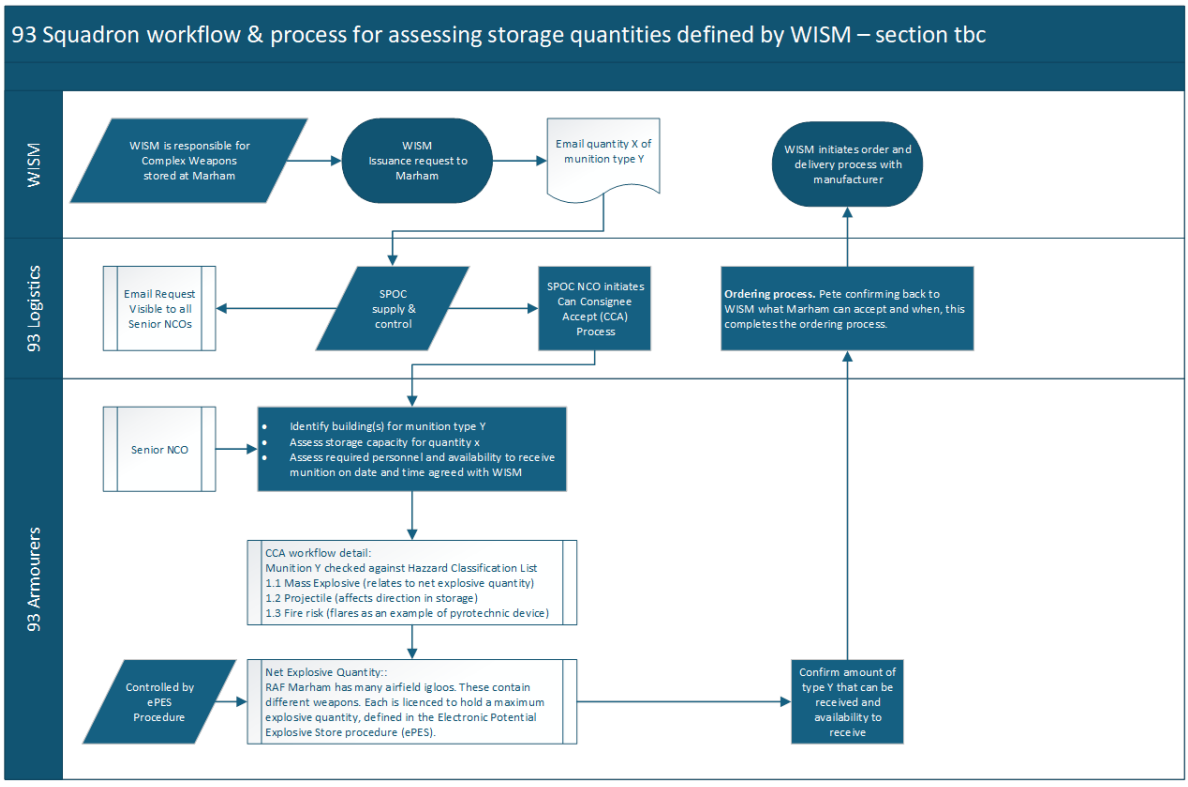
Analysis of Current Workflows and Processes - RAF Marham 93 Squadron (Armaments)

During the Discovery Phase, we conducted an analysis of the six key workflows and processes (bulleted list). Three of these, highlighted in bold below, are presented within the main paper as examples, illustrating the level of detail captured. The remaining

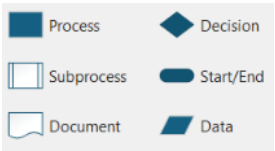
additional workflows are provided in Section 10.2 of the Appendices, for further reference and review:

- **Assessing munitions storage quantities defined and requested by WISM.**
- **Receiving munitions (type 'Y') at RAF Marham.** The following diagrams reference munitions quantity 'x' and type 'y' as blanket terms for all munitions and quantities.
- **Complex Weapon issuance (Deployments**).
  - **Off site.**
  - On site.
  - Normal deployment – full governance.
  - Fast deployment – concession.
- Munitions replacement requests for storage (By RAF Marham 93 Squadron).
- Station level deployment to squadrons (receipts and issues).
- Munition disposals workflow governed by DSA03.

Assessing Munition Storage Quantities (Defined and Requested by WISM)



Legend:



- **WISM:** WISM is responsible for mission planning and determines long term storage verses quicker turn around for deployment. As such, WISM determines that RAF

Marham needs to store a quantity of a certain CW and wants to ship that quantity to RAF Marham.

- **WISM:** requests RAF Marham to confirm the issuance of munition Y quantity X.
    - The request for issuance of a munition to RAF Marham is sent by email from WISM (Flight Sergeant responsible).
- **93 Squadron Logistics:** receive this email to a single point of contact (SPOC), and requests are visible to Snr. NCOs (armourers).
    - Access is under the responsibility of Snr. NCO Logistics, who is responsible for supply control logistics, including allocation.
    - Snr. NCO Logistics must confirm back to WISM the ability of Marham to be able to receive and store the munition type and quantity.
    - Can Consignee Accept (CCA) refers to a process that the SPOC NCO initiates, to determine if Marham can store quantity X of said munition Y.
- **CCA process:** is handled by Snr. NCO Armourer and detailed below. The result of this process is communicated to Snr. NCO Logistics.
    - This requires identifying the appropriate building type for munition Y.
    - Assessing the storage capacity to hold quantity X or reduced amount.
    - Assess required personnel and resources are in place and available to receive the ordered quantity of munition Y, on a time and date agreed with WISM.
- **Ordering process:** Snr. NCO Logistics is responsible for confirming back to WISM what Marham can accept and when, this completes the ordering process.
- **CCA workflow detail:**
    - Munition Y, is checked against the Hazzard Classification List:
        - Mass Explosive (relates to net explosive quantity).
        - Projectile (affects direction in storage).
        - Fire risk (flares are examples of a pyrotechnic device).
- **Net Explosive Quantity:**
    - The Explosive Storage Area (ESA) contains a number of explosive storage houses (ESHs). These store all of RAF Marham's CWs.
    - Each ESH is licensed to hold a maximum quantity of explosive by type and amount.
    - The quantity and distance of a store is contained in the electronic Potential Explosive Store procedure (ePES).

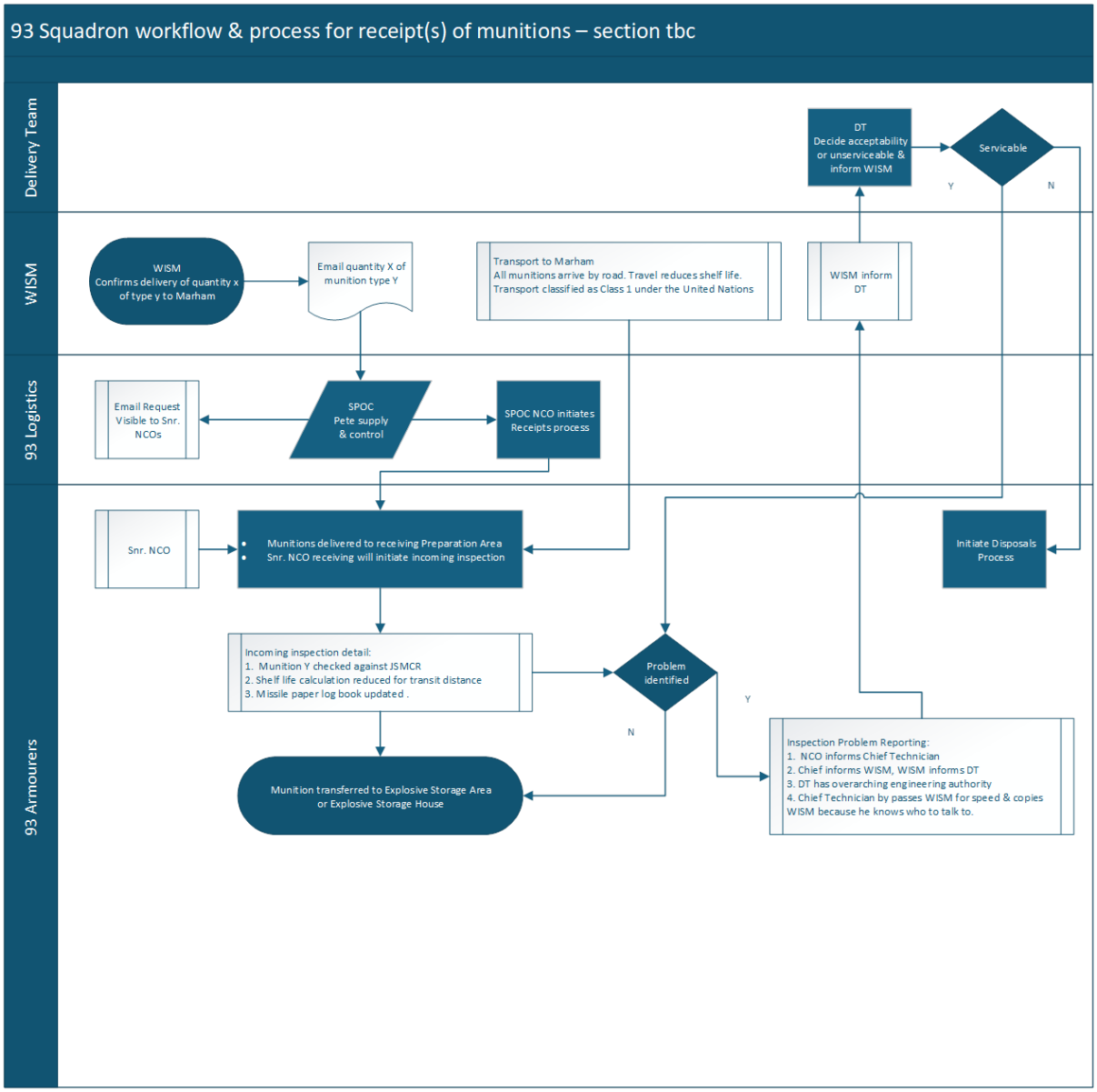
By following this process, 93 Squadron can determine and confirm to WISM its ability to accept quantity X of munition Y. Alternatively:

- It can determine what reduced quantity it can accept.

- Logistics will then raise and manage the ordering and receipt process.

Likewise, RAF Marham can request replacement of munition by sending an email request to WISM.

Receiving Munitions (Type 'Y') at RAF Marham



- **Transport to Marham:**
    - All munitions arriving at Marham arrive by road. Road transport does reduce the munition's SLED.
- **Receipts Workflow:**
    - The Senior NCO receiving, will inspect the munitions type to the JSMCR for life cycle requirements and the CW's ERC for validation of status.
    - The NCO will then calculate the remaining travel distance affecting shelf life.

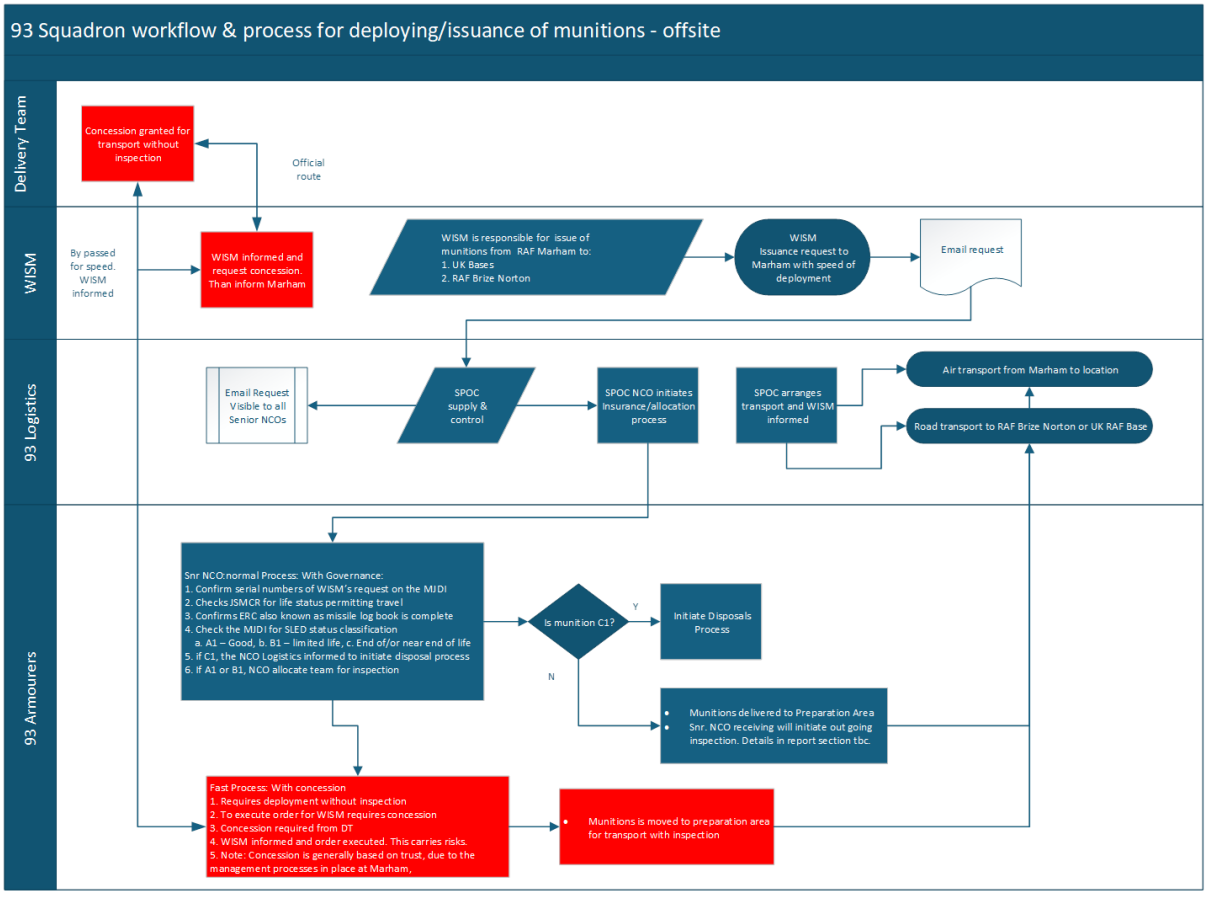
- **The incoming inspection checklist is:**

    1. JSMCR.
    2. SLED calculation.
    3. Updating the ERC.

- **Inspection problem reporting:** If a problem is identified this is reported through official channels.

    - Snr. NCO Armourers will communicate the issue to Chief Technician.
    - Chief Technician informs WISM and WISM will inform the DTs.
    - The DTs have overarching engineering authority and will make the decision on acceptability or unserviceable.
    - Note: Chief Technician, for efficiency purposes (speed), will report the issue to the DTs directly and inform WISM.

Complex Weapon Deployments/Issuance (Off Site)



Note: (Red Boxes: Fast Process requiring concession and carries risk)

Issuing munitions: Offsite locations

- WISM is responsible for any issue of munitions outside of RAF Marham.
- Issuance of munitions are either to:
    - RAF UK locations (large issues).

- Forward operating bases, via RAF Brize Norton.

- **Transport from RAF Marham is either:**
  - Air Transport from RAF Marham to the location identified.
  - Road transport to RAF Brize Norton or to any determined UK location.
    - All road transport requires escort and must comply with strict governance.
  - Note: Any transport affects the munition shelf life, as determined by the JSMCR.

Speed of deployment:

- **Normal process with full governance.**
  - Senior NCO Armouries will confirm the serial numbers of the requested weapons against WISM request.
  - The NCO will check the JSMCR for remaining life to permit transport and use, then confirm nothing has been missed by WISM.
  - The NCO will confirm that the ERC is up to date and complete.
  - The NCO will check the MJDI, which confirms the SLED status, with three classifications.
    - A1 – good.
    - B1 – limited.
    - C1 – end of/or near end of life.
    - **Note:** Snr. NCO logistics is then informed for disposal process.
  - The NCO will allocate a team, for inspection requiring a physical check of the CWs.
  - CWs will be prepared for transport with full governance in place.

- **Fast deployment, outside of the normal process, requires a DT concession.**
  - This requires deploying munition without inspection.
  - To execute this order from WISM, requires a concession.
  - This concession is issued by the DTs.
  - 93 Squadron send the response to WISM for decision making.
  - WISM then conduct an objective risk assessment.
  - Concession is generally based on trust due to the management processes in place at Marham, but without inspection, risk is increased.

4.3 Examples of SLED and Lifing Restrictions Applied

Manufacturer Parameters and Delivery Teams Caution

CWs are subject to detailed parameters set by manufacturers and MOD Dstl, outlining the conditions under which CWs experience different phases of their lifecycle, such as transport by road or air, storage, or carriage on aircraft ready for deployment. The DTs translate these manufacturer-defined limitations into operational lifing periods, examples of which are captured within the JSMCR, as described in Section 4.2.

Due to a lack of granular, real-world data, the DTs understandably apply a highly cautious approach when interpreting manufacturer guidance. This results in lifing rules that, while safe, systematically underestimate a CW's true service life. Two factors in particular; exposure days (when a CW is removed from its Specialist-to-Type Container) and aircraft carriage hours, are the primary drivers of SLED reductions. Standard penalties are also applied for routine activities such as maintenance. However, when unusual or bespoke incidents occur, judgement calls are required. In such cases, the DTs consult with armament teams before issuing a decision on additional penalties, which often errs on the side of caution, further curtailing SLED.

This reliance on precautionary estimates, rather than precise environmental and usage data, highlights a structural inefficiency. Without innovation, valuable capability is lost prematurely. By contrast, digital monitoring solutions that capture real-time conditions would enable more accurate, evidence-based lifing assessments, preserving weapon availability, reducing unnecessary procurement, and ensuring better alignment between manufacturer intent and operational practice.

The Cost of Data Gaps: Real-World Examples

A recent operational deployment by the RAF Marham armament team illustrates the scale of inefficiency caused by the absence of precise environmental monitoring for CWs. While deployed to a high-temperature region, the team was required to remove 18 STCs (holding 18 missiles) from the conditioned storage area, for only a few hours, twice in the same week.

Because current systems cannot record internal container temperature, the team was compelled to assign each missile 2.5 penalty exposure days for a total exposure of no more than five hours. This conservative estimate, driven by the lack of verifiable data, reduced the SLED and is estimated to have cost the MOD approximately £50,000 in lost capability value.

Had accurate temperature data been captured and reported in real time, the actual impact on missile life could have been calculated precisely, avoiding unnecessary penalty periods and preserving asset value.

Conservative Lifing: Compounding the Problem

This example is not an anomaly - it reflects a systemic issue. Where DTs lack confidence in the integrity of the ERC of a CW, they can reduce its SLED by up to 50% as a precaution. Thankfully, this is relatively rare but when it happens, the value reduction in SLED, and therefore cost, is substantial.

Environmental Control Risks in Overseas Deployments

When CWs are deployed to overseas bases, the reliability of environmental controls (particularly air conditioning) presents a critical challenge. In cases where air conditioning performance cannot be guaranteed, a highly risk-averse approach is mandated. This means that even if CWs remain sealed within their STCs, lifing penalties

are applied based on the maximum potential period during which air conditioning 'might' have been inoperative. The result is an unnecessary reduction in shelf life, driven not by actual exposure but by precautionary assumptions. Such inefficiencies highlight the urgent need for innovative digital monitoring solutions that can provide real-time, verifiable environmental data, ensuring that Shelf-Life expiry is determined by fact rather than estimation.

Cumulative Shelf-Life Penalties from Routine Handling

Current lifing practices impose significant penalties on CWs every time they are removed from their STC. Even a brief five-minute exposure results in the loss of a full day from the SLED, rising to 2.5 days in high temperature 'A1' environments. For weapons such as AMRAAMs, where four missiles are stored within a single STC, these penalties multiply across all munitions simultaneously.

Crucially, these reductions are applied not only during deployment but also for routine activities such as inspection and standard maintenance. For example, when CWs arrive at RAF Marham, simply opening the STC for mandatory checks immediately reduces their usable life. These compounding inefficiencies accelerate unnecessary degradation of valuable stockpiles, inflating costs and driving over-procurement. Addressing this issue requires precise, data-driven monitoring solutions that eliminate arbitrary penalties and ensure that shelf life reflects actual exposure, not overly cautious assumptions.

Strategic Implication

This accumulation of conservative penalties, rooted in the absence of precise environmental and handling data, results in a systematic erosion of high-value CW availability, increased procurement demand, and unnecessary budgetary pressure. Deploying advanced monitoring, analytics, and automated reporting would enable condition-based lifing that preserves operational capability while delivering substantial cost avoidance.

4.4 The Costs and Risk of Doing Nothing

Strategic Imperative: Building Digital Readiness for the Re-Armament Era

The Strategic Defence Review (SDR) provides for a significant increase in investment in CWs, driven in part by the urgent need to replenish stocks depleted by the war in Ukraine. In line with other European nations and NATO allies, the UK is entering a new phase of re-armament to counter emerging global threats in Europe and beyond.

As production ramps up to meet these heightened requirements, it is essential that the next generation of CW stock is supported by a modern, digital lifecycle management process from the outset. Without such a system, the MOD risks repeating the inefficiencies of the current approach, incurring substantial costs through avoidable over-procurement, unnecessary wastage, and excessive personnel time spent on manual processes.

Impact of Staff Turnover and Workforce Burden

High staff turnover within RAF armament teams is a significant challenge, directly undermining both team management and operational deployment. Across the four major ESAs, around 150 personnel are employed. Discussions indicate that approximately 30% of their productive time (equivalent to 45 people at any one time) is consumed by manual, repetitive data-entry and reporting tasks.

This reliance on inefficient, labour-intensive processes not only reduces operational effectiveness but also negatively affects workforce morale, contributing to the elevated staff turnover rates currently observed. In essence, highly trained personnel, whose skills are critical to frontline capability, are being diverted away from value-added tasks to maintain outdated manual lifing systems.

By digitising these processes, the burden on personnel can be substantially reduced, freeing valuable expertise to focus on operational readiness and mission-critical activities, while improving retention and overall productivity.

In addition, by embedding digital monitoring, analytics, and automated reporting into CW sustainment from day one, the UK can safeguard its investment, maximise operational availability, and ensure that every CW delivered contributes its full potential to Defence readiness.

Risks of Maintaining the Status Quo

A prevailing mindset within some areas of Defence could be described as ‘if it isn’t broken, don’t fix it’. While current teams would continue to deliver under existing processes, the absence of a Digital Twin solution means that the same systemic issues will persist, with significant implications for effectiveness, efficiency, and readiness.

Key challenges of maintaining the status quo include:

- **Excessive manual workload:** Around 30% of time across 150 personnel, equivalent to 45 people, remains tied up in repetitive manual tasks.
- **Sustained high staff turnover:** Continued inefficiencies and workload pressures exacerbate retention issues, as already highlighted in workforce reports.
- **Slower overseas deployment:** Current processes delay mobilisation, reducing the speed and lethality of response during deployment by 20-30%. Our rationale is: a team of 10 to deploy 20 weapons would normally have 3 staff preparing the documentation (variety of rank 1 x SNCO, 1 JNCO & 1 AS1). If the process were digitally assisted, those individuals could remain focused on the primary task, thereby speeding up the entire process. Also, without the human input, the possibility of the variety of lifing metrics being missed or incorrectly inputted will be reduced dramatically. This means that when the weapons arrive in theatre, they can be implemented and used more quickly with the DTs consultation.
- **Extended training requirements:** New personnel take longer to reach effectiveness due to the complexity and subjectivity of manual reporting systems.

- **Lost opportunity for data-driven decision-making:** Without digitisation, Defence cannot realise the 'softer benefits' set out in Sections 5 and 6, such as improved senior-level oversight, enhanced decision-making, and greater alignment with Defence's digital backbone.

In short, while the system is functioning, it is far from optimal. Continuing with legacy processes represents not only higher costs in terms of operational capability, but also the manpower burden that will compound over time.

5. Proposed Solution

5.1 Strategic Approach, Aims and Objectives

As already evidenced the management and control of CWs relies on a great deal of manual data entry, and ad-hoc process control leading to:

- Inconsistent data informing poor decision making resulting in overly cautious shortening of asset life (increasing costs).
- Lack of visibility of overall capability.
- Increased costs due to manual effort required and process inefficiency.
- Potential for increased safety risk of using a weapon beyond safety limits due to inaccurate recording of environmental data.

Our solution aims to address these issues by creating a single digital data model (single truth) to describe the weapons landscape, which is automatically populated with high quality data, and managed via a controlled, secure, digital process.

The effective management and sustainment of the UK's CW arsenal can only be achieved through a comprehensive programme of digitisation. Current processes rely on fragmented, ad-hoc data models that are incomplete, highly manual, and prone to human error (often distributed across multiple spreadsheets). By establishing a single, high-quality digital data model, the MOD can unlock significant operational and financial benefits:

- **Centralised Data Environment** – providing controlled access for relevant stakeholders while maintaining the highest levels of security.
- **Automated Data Collection** – reducing manual input, improving accuracy, and lowering In-Service Support (ISS) costs.
- **Data-Driven Decision-Making** – enabling predictive analysis, digital modelling, and AI-supported processes for more accurate, timely, and resilient decisions.

The transition to a digitised model offers far more than efficiency gains. It creates a strategic data asset: a real-world dataset of immense value for future innovation. Such a dataset can inform manufacturing processes, sustainment strategies, simulation and wargaming activities, and operational decisions, ensuring CWs are utilised to their maximum potential throughout their lifecycle.

Delivering this transformation requires careful planning. A successful approach should be modular and incremental, allowing independent development of discrete programmes while minimising interdependencies. This ensures early wins in efficiency and cost savings, while also providing a structured roadmap for long-term integration across weapons systems and wider MOD platforms.

Correct technology and partner selection is essential. Solutions must be designed for 10+ years of operational relevance, with flexibility to integrate emerging technologies without requiring wholesale replacement of previous investments. Leveraging proven

solutions from other industries, appropriately tailored to the unique requirements of the Defence sector, will accelerate delivery while reducing risk.

The proposed digital transformation is structured around three interdependent but independently deliverable pillars:

1. **Integrated Process Management** – delivered via secure platforms (e.g., Babcock/SharpCloud) to streamline workflows and governance.
2. **Automated Data Collection and Asset Location Management** – provided by Convert Technologies, ensuring continuous, accurate capture of in-service data hosted and available via secure platforms.
3. **Enhanced Asset Utilisation and Lifecycle Extension** – through frameworks developed in partnership with BAE Systems and Convert Technologies, enabling extended shelf life and maximised return on investment.

Together, these initiatives establish a secure, resilient, future-proof digital ecosystem for CW management, delivering immediate savings, enhanced decision-making, and long-term operational advantage for Defence.

5.2 System Architecture and Vision

The proposed solution is built around a secure, centralised digital architecture, designed to integrate seamlessly into existing MOD environments while delivering transformative improvements in accuracy, efficiency, and asset lifecycle management.

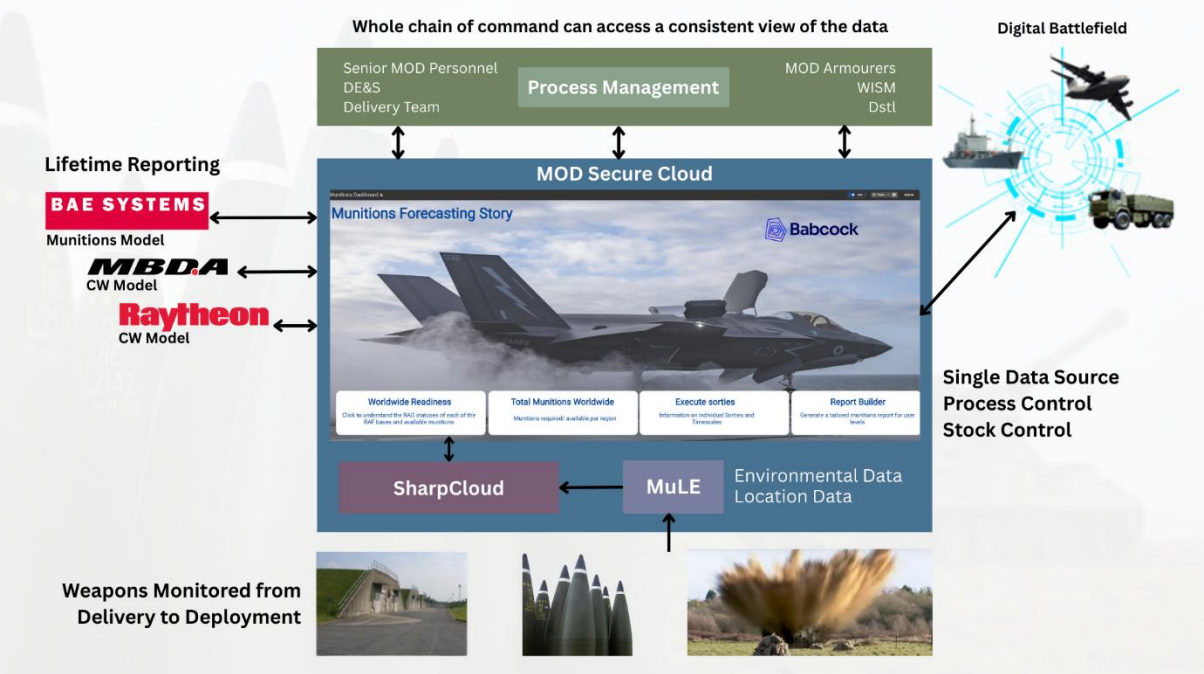


Figure 1: High Level System Architecture

At the core of the system:

- **Secure Centralised Data Environment.**
  All data is hosted and accessed as a Single Truth source via a secure MOD cloud

infrastructure (with OFFICIAL SENSITIVE or SECRET security classification). High level security ensures resilience, compliance, and protection of critical Defence information, and provides a single source for operational management throughout the command chain, as well as greater potential for integration with other digital processes.

- **User Access and Process Management.**
  Stakeholders interact with the system through SharpCloud, a proven platform currently operational in the management of Babcock's Nuclear Submarine Support programme. SharpCloud provides powerful tools for process flow, user management, and data visualisation, enabling a fully digitised workflow for weapons procurement and in-service lifecycle management. Its adaptability offers future potential for integration into broader RAF and tri-service asset management frameworks.
- **Automated Data Capture via MuLE Tags.**
  Data is collected through Convert Technologies' Munition Lifetime Extension (MuLE) tag, an active device permanently attached to the munition case. Each tag combines location tracking with advanced environmental sensors to record temperature, humidity, vibration, and shock with high precision. Sensor data is transmitted securely via low-infrastructure radio signalling to the MOD cloud environment.
    - Minimal support required.
    - Long operational lifespan (5-10+ years battery life).
    - Robust management and security features.
- **Intelligent Munitions Modelling.**
  The final layer of the architecture provides automated digital modelling, leveraging the continuous sensor feed to assess the true condition and lifing parameters of each munition. This enables:
    - **Accurate Shelf-Life prediction** based on real-world data.
    - **Optimised asset utilisation** by extending munition service life where possible.
    - **Real-time capability reporting**, shifting assessment from stock-level to true operational readiness metrics.

This architecture delivers a step-change in CWs management, moving away from error-prone manual processes toward a data-driven, predictive, and proactive system. Beyond extending munition lifespans, it enhances confidence in operational decision-making, reduces unnecessary procurement, and ensures the MOD maintains a ready, sustainable arsenal at lower cost. Further benefits are leveraged by bringing CWs management into the SECRET digital arena allowing integration with existing simulation and planning services across the MOD.

The MOD already recognises the value of data in driving better-informed decision-making. For example, recent initiatives include X-raying CWs to track their structural integrity over time, as well as X-ray inspections of 155mm shells by BAE prior to delivery to RAF Kineton and other bases. These efforts provide valuable insights into weapon

condition and highlight the importance of continuous monitoring. Project MERCURY builds on this foundation, incorporating such initiatives into a comprehensive digital 'through-life passport' (see Section 8.3) that captures and connects condition, usage, and environmental data across the entire lifecycle of each weapon.

5.3 Process Management with SharpCloud/Babcock

At present, much of the CWs through-life process is handled via disparate spreadsheets and manual, paper-based systems between DTs and front-line MOD units. These fragmented methods create inefficiencies and risks:

- Excessive overheads in time and effort.
- Inconsistent data quality.
- A tendency towards overly conservative assessments of high-value assets, driving unnecessary cost.
- Difficulty in accessing the full aggregated view at SECRET.

A digital, web-based data acquisition process management system would streamline workflows, improve data quality, and enable faster, more accurate decision-making at SECRET for Key MoDNet Senior stakeholders.

SharpCloud, in partnership with Babcock, is already proven in delivering services in Defence at OS/SECRET: the solution is deployed within MOD's Zone 1 secure cloud environment and supports the Defence Nuclear Enterprise with over a 1000 Subscriptions providing a number of key decision support capabilities. This tool is also used in Defence Digital, TAC Sys, StratCOM, DE&S for various use cases. Its strength lies in simplifying complex problems and visualising and modelling relational data.

For Complex Weapons, SharpCloud could provide:

- A key SECRET Weapons decision support capability to inform decision making using data collected by MULE.
- Real-time decision support capability for local Squadron levels right up to High Command, via a single truth data model.
- Through-life stories to enable SECRET digital reporting and key insights.
- Integration with other key SECRET systems such as PARMIS and ingest weapons stock and condition data to provide replenishment timelines.
- Strike-force capability reporting across the MOD estate, with potential to integrate other assets and capabilities.

Together, SharpCloud and Babcock could provide a key decision support capability and proven platform, available at the different security tiers to replace outdated manual processes with a robust, secure, and scalable solution, delivering both efficiency gains and greater operational confidence.

SharpCloud/Babcock when challenged by the RAF recently developed a demonstration tool for Weapons Management Reporting and Planning, built on dummy data. This prototype focuses on some ideas for the front-end reporting and strategic planning tools

to support both senior stakeholders and operational users. Combined with the ability to use this toolset at the different security tiers this makes deployment of a real system possible and rapid.

Figure 2: Babcock Munitions Management Reporting and Planning demonstration

The next phase is to align this SharpCloud capability with the ongoing TD-Info Digital Twin review under Project MERCURY. This will ensure that user requirements across both senior decision-makers and front-line personnel are fully captured and integrated, with the goal of providing a single data version of truth that is consistent for all stakeholders at any point in time. Defining these needs across multiple user groups will be essential to guide the design of a robust, scalable, and fully deployable solution at whatever level of classification the MOD require.

5.4 Automated data collection with MuLE

Convert Technologies, supported by Astute Electronics, is working with BAE Systems on a location and environmental reporting system initially designed for General Munitions. The project is well underway using proven technology components, and further adaptions to support CWs environments have been considered during the Discovery phase.

The Munitions Lifetime Extension (MuLE) program will feed automatically collected environmental data into a comprehensive Munitions Ageing Model which can accurately predict the impact of environmental extremes on the munitions' operating condition, highlighting munitions that have exceeded qualified limits or are nearing end of life.

MuLE will offer the MOD savings by increasing munitions SLED, reducing ISS, and improving the overall management of the munitions supply chain with associated benefits in reduced waste, reduced exposure to risk, and more effective operational capability.

The first stage of the program will produce a live demonstration of reporting capability across multiple locations planned for end of Q1 2026, for MOD stakeholders. Although the project was initially focussed on monitoring of General Munitions, the technology is equally applicable to a CWs environment, and the scope of the demonstration should expand to include data collection across RAF-Marham and BAE test facilities, subject to imminent BAE approval.

By combining automated sensing with deterministic lifetime modelling, the system enables accurate SLED assessment and extended weapon life.

At the core is the Munitions Lifetime Extension (MuLE) tag**,** a compact, battery-powered device permanently fixed to weapon cases at manufacture. As the asset moves through the MOD pipeline, the tag continuously collects:

- **Location data** – indoors (via radio) and outdoors (via GNSS), ensuring precise logistics tracking and contextualising sensor readings.
- **Environmental data** – temperature and humidity, critical for life-impact modelling.
- **Shock and vibration exposure** – informing condition assessment and recording transit environments.

Figure 3: Convert's MuLE M-Tag

Figure 4: Temperature & vibration data collected and presented by MuLE

Data is transmitted securely to the central MOD cloud via LoRaWAN, a proven low-power IoT protocol. The MuLE system further enhances resilience with:

- Guaranteed tag-to-cloud data delivery.
- Enhanced security and tamper.
- Support for standard data protocols and over-the-air updates to minimise obsolescence and maintain availability.

This approach provides MOD with a real-time, high-confidence dataset, enabling better informed decisions, reduced wastage, and longer in-service life for high-value assets.

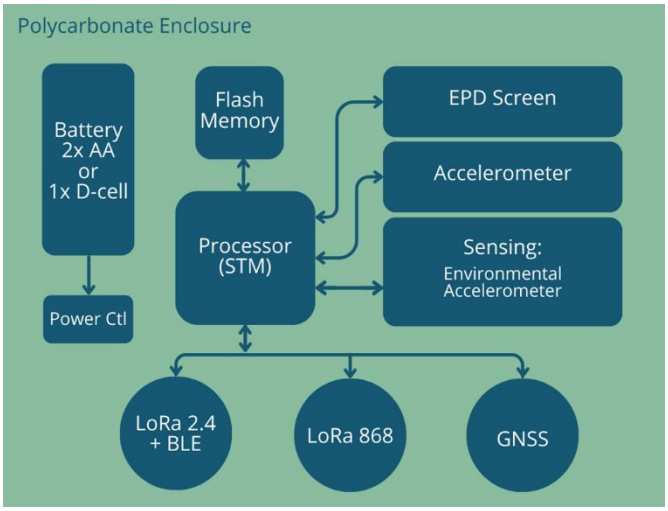
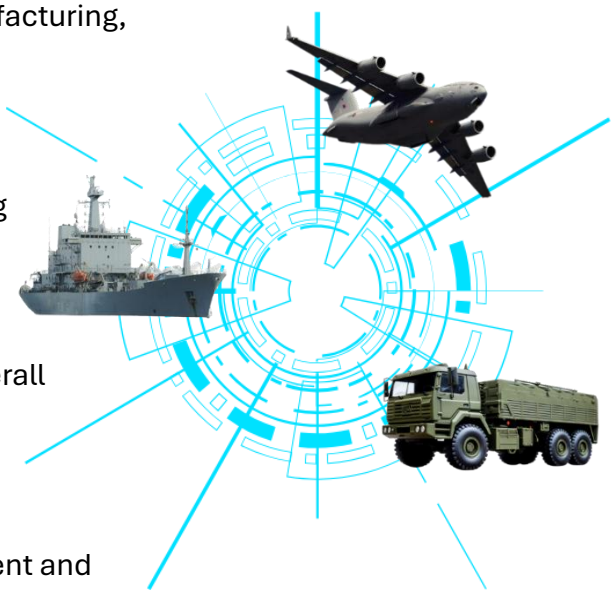


Figure 5: MuLE Tag Installation Block Diagram

5.5 Future Integration and Big Data

Full digitisation of the CWs landscape (at SECRET) enables integration with wider MOD systems, ultimately supporting Digital Battlefield reporting, planning, and capability management. Rather than simply tracking stock levels, this approach delivers a true capability view, combining stock, condition, location, and inter-asset dependencies.

The adoption of automated data recording will generate a large pool of data describing the true life and exposure of CWs assets from manufacture to deployment. A more accurate picture of asset exposure will inevitably result in a better understanding of overall asset condition, informing future manufacturing, qualification and handling processes.



Munitions modelling (under development by BAE Systems as part of the MuLE project) can provide the best refinement and understanding of overall stockpile condition. Fed with accurate, reliable temperature, humidity, vibration and shock data (via MuLE monitoring tags) the model determines the overall impact of environmental extremes on overall effectiveness for individual munitions. This has the potential for very significant savings in:

- Accurate, automated lifetime assessment and reporting.
- Reduced ISS costs.
- Extended SLED and service life.
- Lower risk of sub-optimal performance, ensuring readiness and capability.

Over time, the scale of collected data can also inform manufacturing, qualification, and handling processes, driving continuous improvement across the CWs' lifecycle.

6. Anticipated Impacts of Implementation

The solution proposed in Section 5 will deliver substantial and far-reaching benefits across four key areas: financial savings, resource optimisation, stakeholder productivity, and strategic impact. Together, these outcomes present a compelling case for investment in a digital, data-driven approach to managing the lifecycle of CWs.

6.1 Financial Benefits

Defence expenditure on CWs is significant, with an average annual spend of **£647 million** over the past seven years, including forecasts through to 2025/26. Of this, **£388 million** relates to Air CWs, covering development, procurement, and support. Based on reasonable assumptions, average annual procurement costs are **£194 million**, with a further **£15 million** spent annually on operating costs.

Currently, risk-averse assumptions around SLED result in premature downgrading or disposal of assets. By introducing a Digital Twin solution that accurately reflects the true condition of each weapon, it is estimated that procurement and operating costs could be reduced by **15-20%**. This translates to an annual saving of **£31-42 million,** ongoing in the Air domain alone.

With increased CW investment anticipated under the Strategic Defence Review (SDR), the scale of these savings will only grow. Over time, this represents not only a significant reduction in avoidable expenditure but also a reinvestment opportunity to strengthen frontline capabilities.

Reference: Parallel Parliament 1, **Reference:** Parallel Parliament 2

6.2 RAF Armament Resources

Across the RAF, four key ESAs - Marham, Brize Norton, Lossiemouth, and Coningsby employ approximately **150 armament staff**. Analysis shows that **30% of their time** is currently consumed by manual, repetitive tasks such as record-keeping and physical inspections, representing an annual staff cost of around **£2 million**, ongoing.

A digitised solution would eliminate much of this inefficiency, freeing skilled personnel capacity for higher-value activities such as:

- **Enhanced staff retention**, by reducing frustration from repetitive manual work.
- **Improved Suitably Qualified and Experienced Personnel (SQEP)** numbers, strengthening technical expertise.
- **Cross-service training and skills transfer**, supporting Land and Maritime as well as operational RAF squadrons.
- **Faster overseas deployment**, with a projected reduction in preparation time of **20-30%**, ensuring CWs are operationally ready sooner and contributing directly to greater lethality in theatre.

6.3 Senior Stakeholder Operational Teams (WISM, DTs, RAF HQ Specialist Support)

Although direct engagement with these groups has not yet occurred within the Discovery Phase, their involvement will be a priority during the Elaboration Phase (see Section 7). Based on their roles and interfaces with armament teams, it is anticipated that access to real-time digital data will unlock significant productivity gains. Improved visibility of asset condition, utilisation, and location will allow these teams to shift from reactive to proactive management, streamlining workflows and decision-making across the MOD.

6.4 Wider MOD Stakeholders (NAD and Director of Strategic Programmes)

The digitisation of the CW and munitions landscape represents a transformative opportunity for Defence. Automated data capture will create a rich dataset describing the true life, condition, and exposure of every asset, from manufacture to deployment. This information, available on demand, will:

- **Increase battlefield lethality**, by ensuring weapons are available, reliable, and optimised for use.
- **Inform supply chain and manufacturing planning**, maximising availability at optimal cost levels.
- **Enhance productivity across all personnel** engaged in CW and munitions management.
- **Generate additional, unforeseen benefits** as the value of this unique dataset is realised over time.

The blueprint created for Air CWs can be scaled to Maritime and Land domains. Based on comparable assumptions, the combined potential annual savings across Maritime and Land CWs are estimated at **£21-28 million**. Beyond CWs, the same approach could be applied to any Defence asset requiring lifetime monitoring and reporting.

Summary

The case for action is compelling. A Digital Twin solution for CWs will not only deliver tangible financial savings but will also improve asset availability, personnel productivity, and combat effectiveness across Defence. By embracing digital lifecycle management, MOD will gain a decisive operational edge while demonstrating prudent stewardship of public resources.

Executive Impact Matrix: Benefits of a Digital Twin for Complex Weapons

Impact Area	Current Challenge	Benefit from Digital Twin Solution	Estimated Value / Outcome
Financial	Risk-averse SLED assumptions drive premature disposal and unnecessary procurement.	Accurate, data-driven lifing decisions reduce wastage and extend asset life.	£31-42m annual savings in Air CWs; £21-28m annual savings across Maritime and Land. Growing savings as SDR investment rises.
People and Resources	30% of 150 RAF armoury staff tied up in repetitive manual tasks (~£2m annual productivity cost). High staff turnover and slow training.	Automation of tracking and reporting eliminates low-value tasks, improves retention, increases SQEP capacity, and accelerates training.	20-30% faster overseas deployment; stronger workforce resilience and morale.
Operational Effectiveness	Manual processes delay deployment readiness; limited visibility of weapon condition.	Real-time data on weapon health and location enables faster, assured deployment and increased in-theatre lethality.	CWs ready and effective sooner, improving mission assurance and combat effectiveness.
Strategic / MOD-Wide	Fragmented, manual reporting and isolated pilots; no common digital backbone.	Enterprise-wide digital architecture, aligned with NAD and DE&S 2025 strategy, enabling scalable roll-out across Air, Maritime, and Land.	Integration with MOD digital backbone; blueprint for broader asset lifecycle management.

Key Takeaway

A Digital Twin solution for Complex Weapons will deliver measurable savings, unlock productivity, and provide a step-change in operational readiness. It is a scalable, future-proof approach that aligns directly with MOD's digital transformation strategy and the goals of the National Armaments Director.

7. The Elaboration Phase

The findings of Project MERCURY come at a pivotal moment for Defence, aligning closely with the core values and priorities being driven by the new National Armaments Director (NAD). To ensure these insights translate into tangible improvements, the next step must be a structured Elaboration Phase, a dedicated programme designed to transform recommendations into an actionable and costed implementation roadmap.

It is proposed the Elaboration Phase will run for approximately six months as a funded project, with active participation from key MOD stakeholders and industry partners. Its purpose is to provide the clarity, confidence, and commitment required to move from concept to full-scale deployment.

Primary Objectives

This phase will deliver:

- **Validation of the high-level architecture**, ensuring alignment with MOD's digital backbone and broader Defence Support Strategy.
- **Early identification and mitigation of risks**, reducing uncertainty before full rollout.
- **Refinement of critical requirements**, particularly those shaping the design and operation of the Digital Twin solution.
- **A detailed implementation plan**, including phased timelines, budget allocations, and governance structures.

Guiding Principles

To achieve rapid yet sustainable progress, the Elaboration Phase will be underpinned by several key principles:

- **Leverage existing technologies** wherever possible to reduce risk, accelerate delivery, and secure 'quick wins.'
- **Engage domain experts** to maximise the benefit of existing knowledge and best practice.
- **Adopt modular development**, separating areas of concern to allow for parallel progress and seamless integration via clearly defined data and process interfaces.

Expected Outcomes

This phased approach will deliver early improvements in process efficiency and measurable cost savings, providing confidence to stakeholders and ensuring momentum is sustained. Demonstrating success quickly will also help secure buy-in across Defence and build the foundation for wider adoption.

Delivery Partners

The White Paper process has already assembled a uniquely capable team of partners:

- **Convert Technologies**, experts in advanced sensing and tracking, will deliver tailored weapons monitoring solutions that automate the capture of environmental and location data, ensuring unprecedented visibility of CWs condition and capability.
- **Babcock and SharpCloud**, proven leaders in secure, process-driven platforms, will design and operate the management framework required to integrate digital workflows at the scale and security classification demanded by Defence.

Next Steps

The Elaboration Phase should begin with a formal review of these White Paper (Project MERCURY) findings, convening the Discovery Phase Team and MOD Senior Responsible Owners (SROs). This session will align priorities, agree the scope, and initiate detailed planning. A further key consideration will be how best to expand the scope of the solution beyond Air to include Maritime and Land, maximising Defence-wide benefits.

7.1 Project outputs

Outputs from this phase should include:

- Ongoing discovery phase with key requirements definition.
- Detailed definition of stakeholders and their interrelationships.
- Definition of implementation roadmap defining development phases, and deliverables.
- An indication of overall implementation costs and budget indications.
- Preliminary risk analysis and mitigation.
- Consideration of wider combined forces implications.
- Expansion of project MuLE definition to include CWs.

A key output of this phase should be the inclusion of CWs in the MuLE demonstrations, currently scheduled for end of Q1, 2026. The MuLE brief currently encompasses General Munitions in partnership with BAE Systems. A key output of this development is a comprehensive (though inert) demonstration of tracking and monitoring capabilities to key stakeholders across multiple sites. Extending this brief to include the CWs landscape (e.g. including RAF Marham) would quickly provide valuable proof points in engaging key stakeholders in the capabilities of the program.

7.2 Elaboration Project Team

It is proposed the team should include existing domain experts from Convert Technologies and Babcock, as well as individuals from a wider context to provide overall governance required for signoff, and ultimately approval for the next phase.

The team should include the following roles (individual names to be assigned once agreement to proceed has been authorised).

- **Project Manager:** day to day coordination, management of risks, requirements and overall planning.
- **Chief Architect:** Technical lead on architecture and technology considerations.
- **Business Owner/Sponsor:** Validation of the business case, and value proposition.
- **Steering Committee/Board:** Ultimate authority for approval and funding.
- **QA/Risk Manager:** Quality, risk and compliance management.
- **Developers/Analysts:** Technical domain experts for risk analysis and preparation of prototypes where required.
- **User/Stakeholders:** Validation of requirements, and alignment to day-to-day business needs.
- **'Customer Friend':** from Team Defence Information (TD-Info) to maintain wider enterprise communication.

7.3: Timeline and budget

This phase should aim to be completed in a 6-month period with a focus on fast delivery, with an appropriate budget to support commercial activity.

Final costings for the elaboration phase and a detailed timeline can be submitted once the key outputs have been agreed and documented in partnership with key stakeholders.

8. Strategic and Policy Considerations

8.1 MOD Digital Backbone Strategic Alignment

To remain competitive and mission-ready in today's evolving threat landscape, the UK Ministry of Defence (MOD) must modernise its approach to managing CW systems across their full lifecycle. The proposed solution outlined in Section 5 directly supports the MOD's *Digital Backbone Strategy* and *Defence Support Strategy*, serving as a foundational enabler for both operational readiness and strategic resilience.

The MOD Digital Backbone Strategy sets a bold vision for a digitally empowered Defence enterprise, one that is agile, data-driven, and securely integrated. Key pillars such as the *digital backbone*, *digital foundry*, and an *empowered digital function* are essential to transforming Defence capabilities, and our proposed solution directly supports this transformation through data capture, secure integration, and actionable insight generation.

Reference: MOD Digital Backbone Strategy

Simultaneously, the **Defence Support Strategy** defines how the UK will deliver 'Support Advantage' by modernising military logistics and asset management. Our proposal aligns with this strategy across several critical dimensions:

- **Implementing Asset Management Across the Lifecycle.**
  Our solution provides the technical means - sensors, analytics, and domain-specific knowledge to realise lifecycle management of CWs, initially supporting 93 Expeditionary Armaments Squadron at RAF Marham.
- **Driving Digital Transformation.**
  By enabling precise, real-time data collection, we move beyond generic estimations of SLED to a more accurate, condition-based approach. This addresses a longstanding problem where lack of location, environmental and usage data often leads to unnecessary early withdrawal of weapons.
- **Enhancing Integration with Industry.**
  Our approach fosters closer collaboration with the military-industrial base, enabling smarter through-life asset management and improved platform availability.
- **Building a Resilient Strategic Base.**
  With integrated data systems, environmental monitoring, and predictive analytics, we help strengthen the digital and physical infrastructure needed to support sustained, high-readiness operations.
- **Future-Ready Technologies.**
  We support the adoption of emerging technologies such as AI, automation, and Digital Twins, which are critical to achieving long-term cost savings and operational efficiency.

- **Agile Supply Chain Enablement.**
  Our solution facilitates a bimodal supply chain approach, capable of handling both steady-state logistics and rapid-response scenarios.

The strategy's call for *cross-government and allied interoperability* is supported through our solution's scalable, modular architecture built to integrate across platforms and partner ecosystems.

Reference: Defence Support Strategy

Strategic Defence Review (SDR) 2025 Context

Our proposal also aligns with the direction set by the Strategic Defence Review 2025, which calls for faster innovation, smarter procurement, and a step-change in Defence readiness. The SDR highlights the need to measure innovation cycles in months, not years, while also unlocking greater domestic capability in weapons production and sustainment. These themes are at the heart of our proposed programme.

Reference: Strategic Defence Review 2025

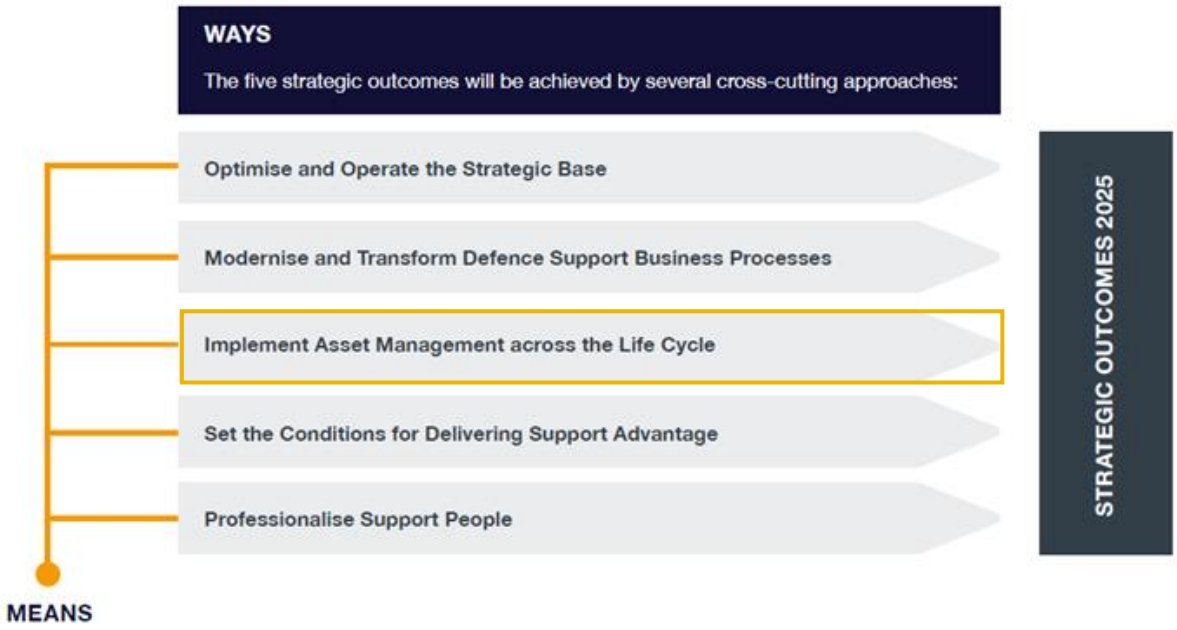


Figure 6. The Five 'Ways and Means' Strategic Outcomes (Defence Support Strategy Overview, April 2022 - Edition 2).

Supporting MOD Strategic Outcomes

This initiative delivers on the MOD's overarching objectives, including:

- Increased platform readiness and operational availability.
- Enhanced through-life capability and asset management.
- Modernisation of Defence logistics and digital infrastructure.
- Improved sustainability and reduced material waste through optimised SLED management.

8.2 DE&S 2025 Strategic Alignment

The proposed Digital Twin 'Elaboration Phase' in Section 7 is directly aligned with the DE&S 2025 Strategy, *Delivering the Edge Through People, Technology and Innovation*.

- **Integration and Digital Backbone.**
  DE&S highlights the need for better connected systems and a secure, cloud-based platform to exploit data. Our solution provides exactly that through a centralised, secure MOD cloud environment integrating SharpCloud and MuLE technologies. This ensures seamless interoperability across Defence's digital backbone.

- **Digital Twin and Virtual Trials.**
  The strategy promotes Digital Twin technology for virtual trials, evaluation, and certification. Our approach embeds real-world digital trackers on weapons (STCs), enabling continuous monitoring of environmental conditions and usage. This real-time data feeds directly into Digital Twin models, reducing reliance on subjective manual processes and accelerating evaluation cycles.

- **Lifecycle Management and Assurance.**
  DE&S calls for digital data at the heart of acquisition and support lifecycles. Our solution incorporates automated data collection, intelligent modelling, and lifecycle forecasting, enabling accurate condition-based assessment, longer in-service life, and improved assurance. This maps directly to MOD's goals of optimising the lifecycle of CWs.

- **Speed and Agility of Delivery.**
  With DE&S emphasising the acceleration of capability delivery to operators, our architecture is designed for speed, consistency, and agility. By reducing manual effort and human error, our system delivers faster, more reliable decision-making and supports quicker deployment of weapons and platforms with greater assurance.

- **Alignment with Capability Centres.**
  The new MOD Capability Centres champion 'doing stuff faster' and delivering innovation at pace. Our solution reflects this mantra: it is modular, scalable, and proven in parallel Defence domains. With consistent delivery methods and a rapid execution model, we are positioned as ideal technology partners to support the Capability Centres in meeting their innovation and speed targets.

In summary, the proposed Elaboration Phase does not simply align with the DE&S 2025 Strategy, it operationalises its intent. By combining secure integration, Digital Twin capability, lifecycle optimisation, and rapid delivery, we enable MOD to deploy CWs more effectively, with more confidence, and at a pace consistent with emerging threats.

As Project MERCURY transitions into production, it offers not only domestic benefits but also a significant export opportunity. The solution could be extended to other NATO members, strengthening allied capability while directly supporting the MOD's strategic objective of doubling UK defence exports by 2030. In this way, Project MERCURY aligns national security priorities with broader economic and industrial goals.

8.3 The Case for Innovation: Complex Weapons Life Extension

CWs are subject to demanding operational environments and extended storage periods. Yet, current approaches to managing their service life often rely on broad assumptions and subjective discussions about factors such as:

- Ambient storage temperature and humidity.
- Handling and transit shock.
- Trundle distance and vibration exposure.
- Cumulative aircraft carriage hours.
- Inter-site and inter-platform transfers.
- Deciphering manual process notes/documents.

In the absence of precise environmental and usage data, lifecycle estimations default to worst-case scenarios, resulting in the premature retirement of still-viable weapons. This not only reduces operational availability but also contributes to waste and increased sustainment costs.

Through recent engagement with RAF Odiham and RAF Marham, we've observed first-hand the limitations of current asset tracking and SLED estimation methods. These insights inform our recommended approach: to shift from assumption-based to evidence-based life extension, powered by real-time telemetry, predictive analytics, and Digital Twin technology.

Complex Weapon 'Through-Life Passport'

Our solution can evolve to provide the basis for a 'complex weapons through-life passport', which could be described as a secure, digital, end-to-end record that stays with each individual weapon system from the moment of manufacture to its eventual disposal, capturing and updating key data on location, condition, maintenance history, ownership status, and operational usage. Acting as a single authoritative source of truth, the passport would be accessible to authorised armourers, logisticians, engineers, and decision-makers across the MOD and industry partners, enabling real-time tracking, better inventory accuracy, proactive maintenance scheduling, and enhanced safety and compliance. By integrating data from manufacturing, storage, transport, deployment, and demilitarisation stages, it would provide full lifecycle visibility, support regulatory and contractual obligations, and reduce the risk of misplacement, degradation, or capability gaps.

Conclusion: A Strategic Imperative

The time is right to act. By embracing digital lifecycle management for CWs and general munitions, the MOD can reduce waste, enhance readiness, and modernise its support capabilities in line with its most critical strategic priorities.

Our programme delivers the technical means, the domain expertise, and the stakeholder alignment necessary to implement this transformation today starting with 93 Squadron, and scalable across the wider Defence enterprise.

9. About the Authoring Organisation

9.1 Contact Information for Follow up

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Team Defence Information Overview

As a trusted membership organisation, Team Defence Information (TD-Info) brings together Industry and the MOD, collaborating to optimise the value from business information working across Team Defence. As a trade body, funded by Industry with MOD as partner, TD-info acts as a catalyst and facilitator whose activities complement those of fellow trade organisations ADS and techUK. TD-Info represents the interests of both suppliers of ICT services and sometimes overlooked, the interests of Industry users of the same ICT services. Typically, these users are materiel manufacturers and through-life support providers to the MOD. TD-Info members include prime contractors and SMEs involved in Defence supply chains and support networks. Our joint Three Star level Industry-MOD governance drives coherence and continuity, with representation through to the Defence Suppliers Forum. Participation in TD-Info activities provides strong 'multiplier' benefits. Working in a trusted forum, collectively we can draw on real-world use cases involving Team Defence (i.e. MOD and Industry) and engage subject matters experts from varied disciplines to develop pragmatic, common solutions. TD-Info promotes using global standards and inter-operable ways of working designed to increase efficiency and effectiveness. Corporate knowledge is captured and shared via our members' website. Within Team Defence Information, our collective efforts are directed ultimately at achieving Defence superiority.

10. Appendices

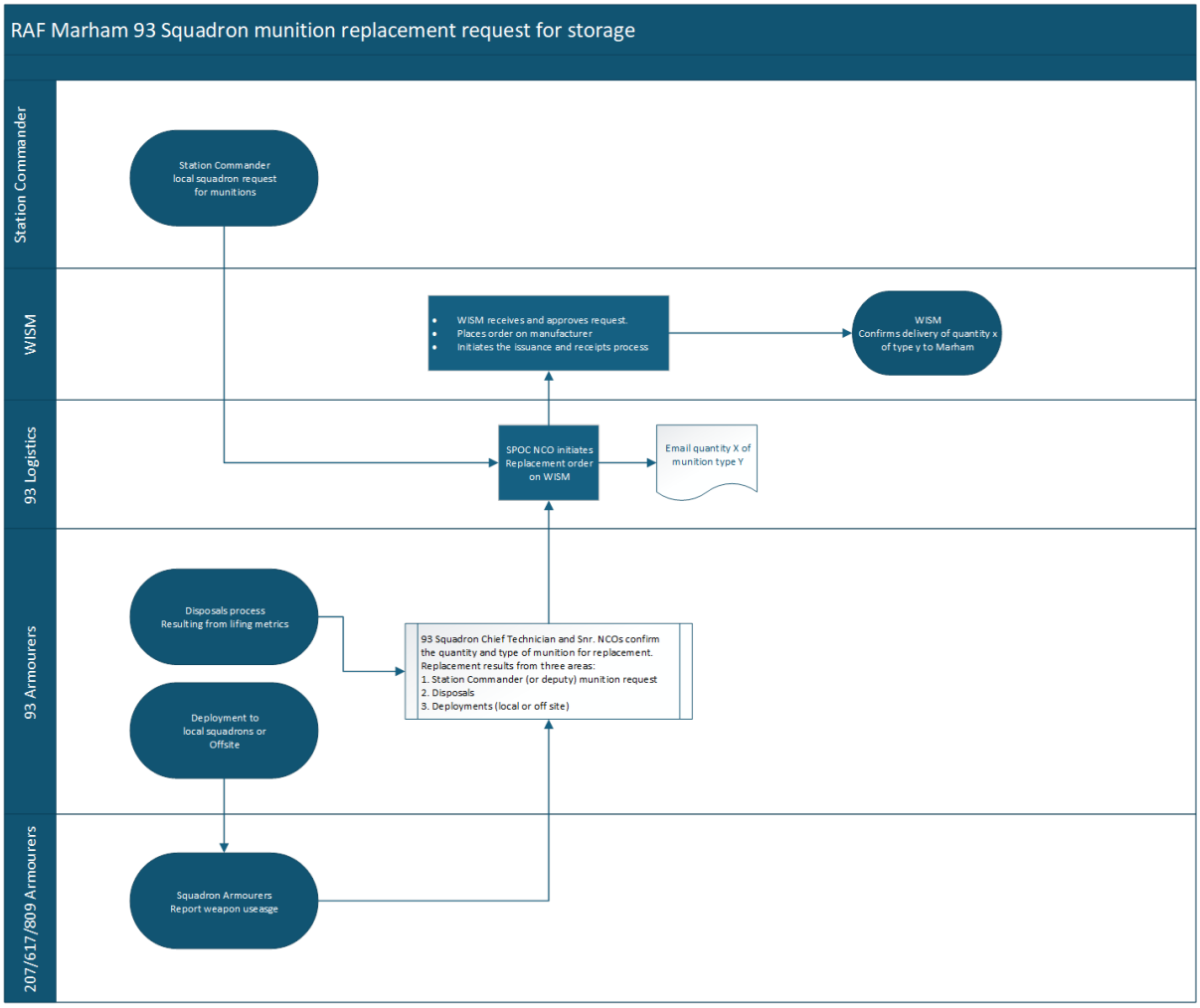
10.1 Glossary of Terms

Abbreviation	Explanation
ACH	Air Carriage Hours
AMRAAM	Advanced Medium Range Air-to-Air Missile
ASRAAM	Advanced Short Range Air-to-Air Missile
AS1	Air Specialist (Class 1)
ATM	Acquisition Training Munition
Brimstone	Air-to-ground missile, long range and "fire and forget" capable
CCA	Can Consignee Accept
CWs	Complex Weapons
DE&S	Defence Equipment and Support
DFR	Daily Flight Report
DSA	Defence Safety Authority
Dstl	Defence Science and Technology Laboratory
DTs	Delivery Teams
EED	Electro Explosive Device
ePES	electronic Potential Explosive Store procedures
ERC	Equipment Record Card
ESA	Explosive Storage Area (and Preparation Area)
ESH	Explosive Storage House
ESS	Electronic Support System
FMS	Foreign Military Sales
GNSS	Global Navigation Satellite System
HACH	High Aircraft Hours
ISS	In-Service Support
JSMCR	Joint Services Munitions Control Register
LoRaWAN	Long Range Wide Area Network
Meteor	Beyond-Visual-Range Air-to-Air Missile
MIRD	Munitions Incident Report D
MJDI	Management of the Joint Deployed Inventory
MOD	Ministry of Defence
MOD Forms 700-719 Logbook 714, 6580, Equipment Record Card/MTI Logbo 714	Different names for the same thing - They provide a full history of where each Missile/Bomb Component has been stored, how, where and how long, which armourers use to provide a Life Ex date for each asset
MoDNet	MOD's Internal communication and collaboration system
MuLE	Munition Lifetime Extension
NAD	National Armaments Director
NATO	North Atlantic Treaty Organisation
NCO	Non-commissioned officer
NEQ	Net Explosive Quantity
NSN	NATO stock numbers
OME	Ordnance Munitions and Explosives
Paveway IV	Radar guided beyond-visual-range air-to-air missile

RAF	Royal Air Force
RH	Relative Humidity
SDR	Strategic Defence Review
SLED	Shelf-Life Expiry Date
SMEs	Small and Medium-sized Enterprises
SPOC	Single point of contact
SQEP	Suitably qualified and experienced person
SRO	Senior Responsible Owner
STC	Specialist-to-Type Container
Storm Shadow	Long-range air-launched cruise missile
TD-Info	Team Defence Information
T&E	Test and Evaluation
UDL	Ultimate Disposable Life
WISM	Weapons In Service Management

10.2 Additional Current Workflow and Processes

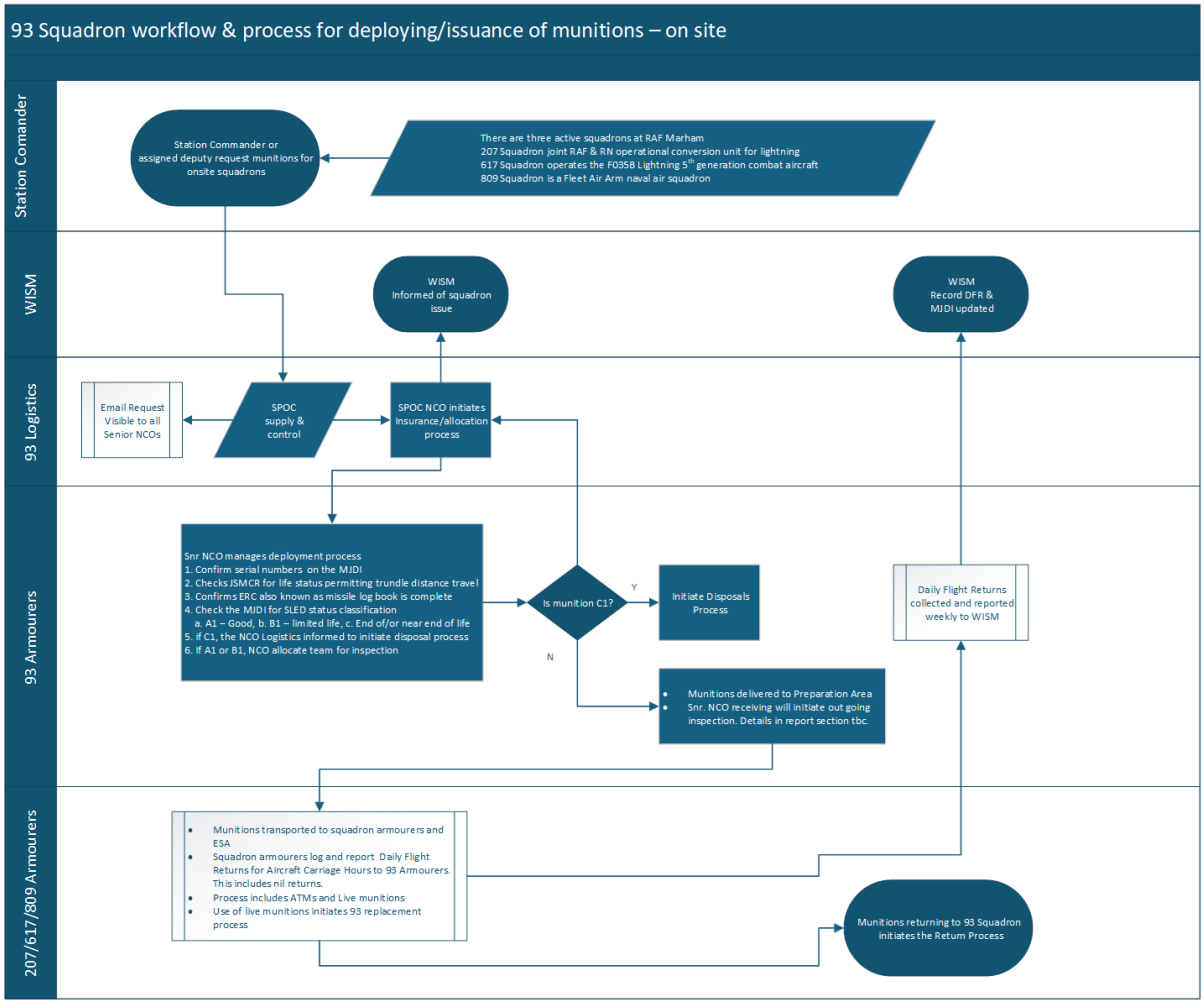
Munition Replacement Requests for Storage (by RAF Marham 93 Squadron)



- **These requests can result from three sources:**
  - Deployment offsite.

- Disposals resulting from lifing metrics or weapon classed as unserviceable, which also includes any weapons returned damaged by a squadron.
- Station Commander requests for local Squadrons that are used and not returned to 93 Squadron ESA stocks.
    - A request of this type is essentially part of an ordering process and controlled by 93 Squadron Logistics SPOC.
- The impact on stock levels is monitored by the Chief Technician and Senior NCOs.
- The Chief Technician can initiate a replacement request through 93 Squadron Logistics SPOC.
- As with the WISM initiated storage process, the SPOC NCO will send a similar email to WISM, requesting quantity X of munition type Y.
- WISM receives and approves the request, then initiates purchase with the manufacturer.
- Once everything is confirmed. WISM will initiate the same process for issuance of quantity X of munition type Y.

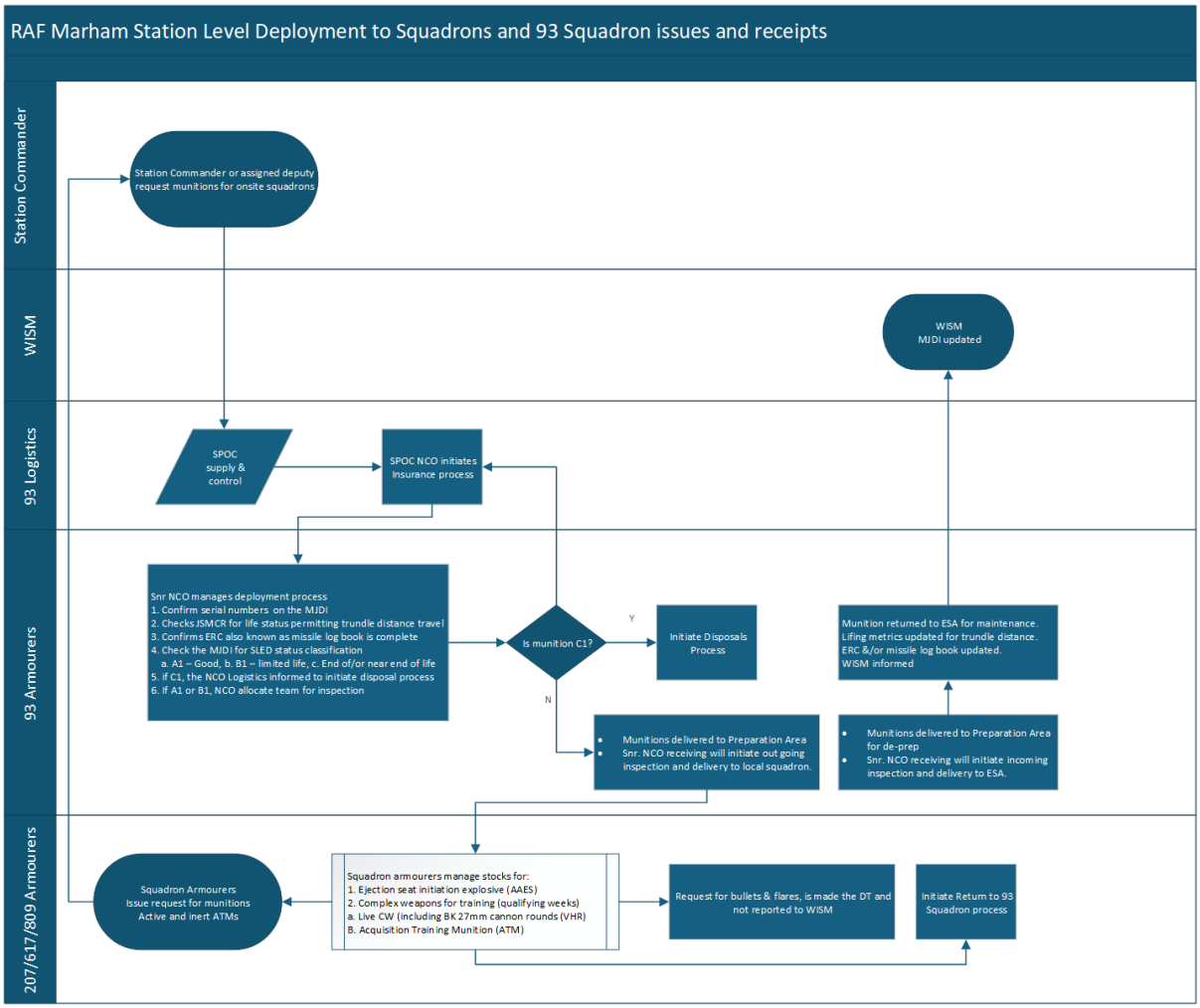
Complex Weapon Deployments/Issuance (On Site)



Issuing weapons: Onsite locations

- 93 squadron is responsible for issuing any weapon to 207, 617 and 809 squadrons based at RAF Marham.
- They then manage any return to stock and reporting to WISM.

Station Level Deployment to Squadrons (Issues/Receipts)

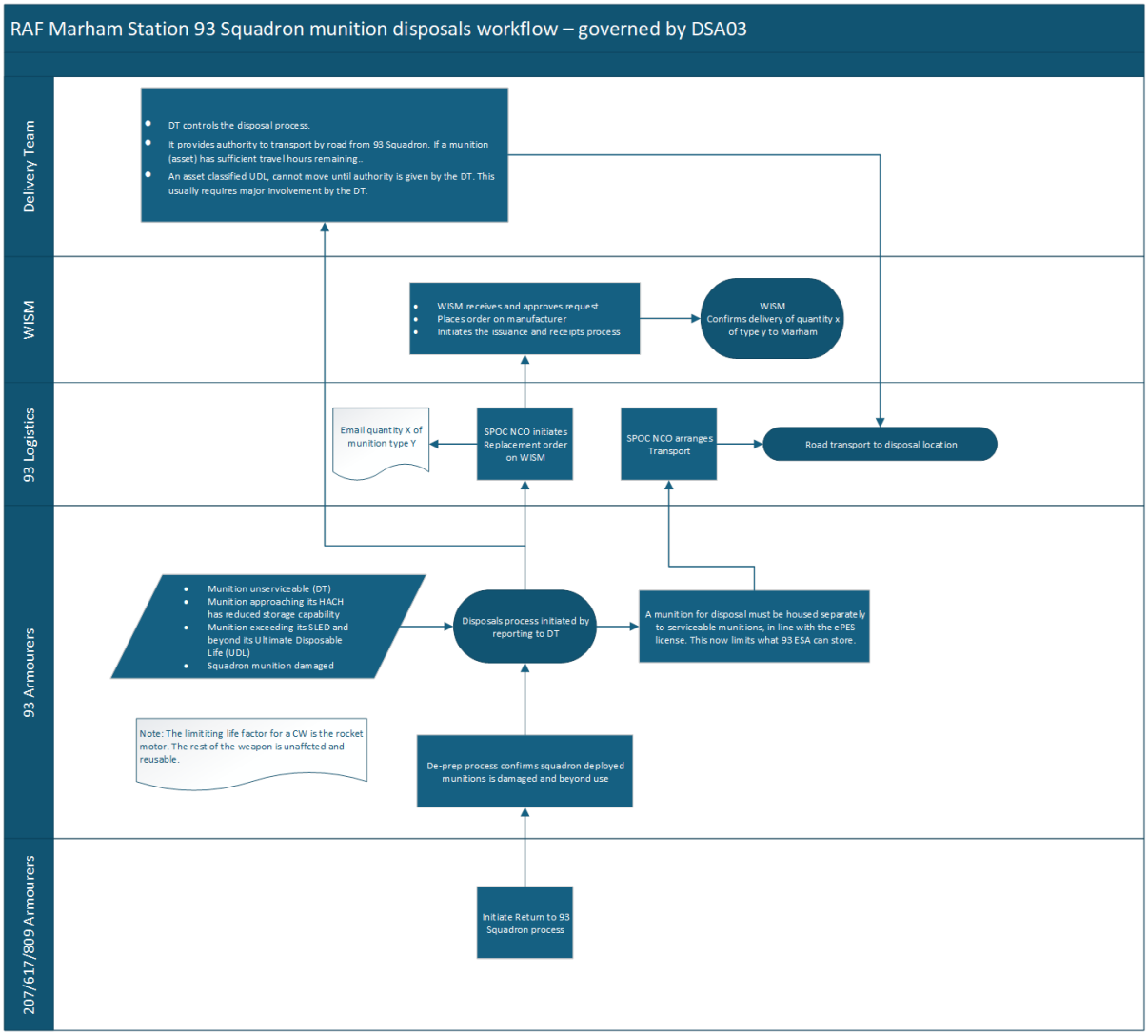


- **RAF Marham supports three squadrons:**
  - 207 Squadron is the joint RAF and Royal Navy Operational Conversion Unit for Lightning.
  - 617 Squadron is now flying the F-35B Lightning fifth-generation combat aircraft.
  - 809 Squadron is a Fleet Air Arm naval squadron flying F35Bs operating from RAF Marham.
- **Each squadron operates with its own armourers and squadron requests include stock for:**
  - Ejections seat initiated explosive (for the aircraft assisted escape system).
  - CWs for training use (qualifying weeks).
    - Training munitions knows an Acquisition Training Munition (ATM).

- No warhead, but fully active to support the same interaction as a live CW.

- Squadron armourers request complex weapons deemed Very High Readiness through the station commander.
- 93 Squadron will issue and update WISM. Any weapons returned will be received, stored and WISM updated.

Munition Disposals Workflow Governed by DSA03



- **DSA03:** refers to a series of guidance documents published by the UK Ministry of Defence (MOD) and the Defence Safety Authority (DSA) related to safety regulations.
- **Specifically:** DSA03 covers a range of topics, where DSA03-OME is pertinent to 93 Squadron, which applies to munitions they store and deploy.
- **DSA03-OME:** Defence Ordnance, Munitions and Explosives. This series of documents provides guidance to ensure risks associated with ordnance, munitions, and explosives are minimised during all stages of their lifecycle (acquisition, in-service, operational, ranges, major accident control, and military laser safety).

A munition is classified as:

  - Serviceable or non-serviceable.
  - A munition approaching its High Aircraft Carriage Hours (HACH) has reduced storage capability.
  - A munition that has exceeded its shelf life and is now beyond its Ultimate Disposable Life (UDL).
- The DTs control the disposal process. It also provides the authority to transport from 93 Squadron.
- A complex munition is also known as an asset, may have sufficient travel hours that allow it to be transported by road.
- An asset classified UDL, cannot move until authority is given by the DTs. This usually requires major involvement by the DTs.
- As a general point, for CWs, it is the rocket motor that is the limiting life factor. Much of the rest of the weapon is unaffected and is reusable.
- Weapons requiring disposal have a major negative impact on storage capacity.
- In RAF Marham's ESA there are ESHs and Preparation Areas.
- ESHs are licenced to house certain quantities and types of weapons.
- A weapon for disposal must be housed separately to serviceable weapons, in line with the licensed building type and explosive quantity.
- In short, this impacts directly on 93 Squadrons over all ability to maximise storage capacity and can reduce the number of weapons that WISM wants to send to RAF Marham.

TD-Info Digital Twin (Asset Tracking Team)

15th September 2025

End of Document