IRREVERSIBLE NUCLEAR DISARMAMENT

UNIVERSITY of York

Irreversibility and Nuclear Disarmament: The Case of Denuclearising the Royal Air Force

Dr Nick Ritchie and Dr John Walker

York IND Research Report#3

April 2024

IRREVERSIBLE NUCLEAR DISARMAMENT: THE CASE OF DENUCLEARISING THE ROYAL AIR FORCE

York IND Research Report#3

Dr Nick Ritchie and Dr John Walker

Dr Nick Ritchie is a Senior Lecturer in International Security at the Department of Politics and International Relations, University of York, UK, where his research examines the global politics of nuclear weapons and nuclear disarmament. After completing his PhD thesis at the University of Bradford in 2007 on the evolution of US nuclear weapons policy after the Cold War, Nick spent four years researching and teaching at Bradford's Department of Peace Studies before joining York in 2011. He previously worked for five years at the Oxford Research Group, an independent Non-Governmental Organisation working with policy-makers and independent experts on the challenges of global security and nuclear disarmament. Recent research has focused on the international movement to ban nuclear weapons culminating in the Treaty on the Prohibition of Nuclear Weapons in 2017. His work has been funded by the UK Foreign, Commonwealth and Development Office, Austrian Ministry of Foreign Affairs, Economic and Social Research Council, Joseph Rowntree Charitable Trust and Nuclear Education Trust.

Dr John R Walker was Head of the Foreign and Commonwealth Office's Arms Control and Disarmament Research Unit (ACDRU) from December 2014 to May 2020 when he retired from the FCO. He joined ACDRU in March 1985. John's main focus was on the Biological and Toxin Weapons Convention (BTWC), the Chemical Weapons Convention (CWC), the Comprehensive Nuclear Test Ban Treaty (CTBT), and the UN Secretary-General's Mechanism for investigating allegations of CBW use. He was a member of the UK's Chemical Weapons Convention Steering Group and its Technical Sub-Group during the negotiations and represented the UK during the Preparatory Commission's Working Group B Expert Groups on verification issues. In addition, his work also included UK nuclear weapons and arms control history and nuclear disarmament verification. He is currently a Senior Associate Fellow at the European Leadership Network and a Senior Associate Fellow at the Royal United Services Institute.

April 2024

University of York, UK

Cover photo: Panavia Tornado GR1 aircraft

Introduction

This report examines the extent to which the denuclearisation of the RAF in the 1990s following the withdrawal of the WE177 gravity bomb can be understood as 'irreversible'. This is part of a broader body of work sponsored by the UK and Norway on 'irreversible nuclear disarmament'.

'Irreversible' is understood in a practical rather than an absolute sense insofar as the time, cost and difficulty of reversing a decision to relinquish nuclear weapons renders such a decision as to all intents and purposes irreversible. South Africa is the only country to have developed a nuclear weapons complex and then voluntarily dismantled it and this case has been studied as part of the broader body of work on irreversible nuclear disarmament.[1] The South African nuclear arsenal and nuclear weapons complex was very small compared to the mature nuclear weapons complexes of today's nuclear-armed states.

Absent empirical cases of the denuclearisation of a mature nuclear weapons complex through which to examine 'irreversibility', we can instead examine the denuclearisation of branches of armed services in nuclear-armed states. Primary examples are the denuclearisation of the US army and surface navy and the denuclearisation of the UK army, surface navy and air force. The decommissioning by France of its land-based S3 IRBM fleet, dismantling and conversion of the Plateau D'Albion base and disbanding of the 95th Strategic Missile Wing is a related example.[2]

For the purposes of studying irreversibility in this context, a nuclear weapons complex is understood as a 'large socio-technical system'. This draws on Science and Technology Studies (STS) work on 'Large Technical Systems' (LTS) Actor-Network Theory (ANT) and the social construction of technology (SCOT). These approaches explore how a variety of social, economic, political and technical elements are shaped and assimilated together into a network, or a socio-technical system, rather than taking the existence of the system for granted or assuming the processes and histories that produced it are obvious. Successful socio-technological systems therefore are not politically or technologically inevitable, but contingent upon recruiting and sustaining a diverse set of allies in a large coalition whose interests have been successfully aligned with, or provide essential support for, a system's primary output, for example safe, secure, deployed, and deliverable nuclear weapons.

These approaches are useful, because they show us that sustaining a nuclear weapons capability requires constant work because it won't endure by itself: decisions must be made, programmes must be funded, scientific and industrial sites must be modernised, organisations must work, manuals must be written, expertise must be sustained, new recruits must be trained, technologies must be developed, weapons must be refurbished, missiles and warheads must be tested, politicians must be enrolled, and so on. It takes organisational effort, knowledge, money, and political will to bring a nuclear weapons

[1] Joelien Pretorius (2023).'Working Paper on "Staying the Course: Lessons from South Africa for Irreversibility of Nuclear Disarmament', March.
[2] This is an example of the termination of a leg of a nuclear triad (land-based missile, air-delivered weapons and submarine-based missiles) rather than denuclearisation of an armed service.

complex together and sustain it. If this ‘ecosystem’ of actors, materials, processes and connections dilutes over time, then a nuclear weapons complex as a socio-technical system will start to come apart and become increasingly difficult to put back together.[3]

This case study of the denuclearisation of the RAF highlights the considerable challenges of sustaining *and* re-establishing this part of the UK nuclear weapons complex, which in turn illuminates the challenges of re-establishing a basic nuclear weapons complex following a nuclear disarmament process.

Studying irreversible nuclear disarmament in a practical sense using examples such as the denuclearisation of the RAF is a three-step process:

- First it requires us to map the 'ecosystem' that was necessary to support the WE177 in service and identify its core elements and relationships.
- Second, to trace how the ecosystem changed during and after the decision to withdraw the weapon from service.
- Third, to hypothesise about the challenges of putting a comparable ecosystem back together in order to 're-nuclearise' the RAF.[4]

To be clear, the purpose is *not* to make a case for re-nuclearising the RAF but to use a hypothetical decision to re-nuclearise as a vehicle for developing our understanding of the extent to which nuclear disarmament processes can be rendered practically irreversible.

The study shows that the acquisition of an operational nuclear weapons capability is one thing, retaining it is quite another. The RAF was responsible for the UK deterrent from 1956 when the first squadron of Valiant bombers was declared operational until 1969 when the Royal Navy took over with the deployment of Polaris submarine launched ballistic missiles in the Resolution class submarines. However, the RAF went on to retain a tactical nuclear capability from then until 1998 when the last WE177A gravity bomb was withdrawn from service at RAF Marham. A good deal of effort was required to sustain such a capability – safe and reliable weapons, trained ground crew and aircrew, infrastructure such as storage facilities, a bureaucratic structure to manage the programme, specialised support equipment such as transport containers, security and accident response personnel plus a whole raft of policies, standing operating procedures and training programmes that have to be formulated, implemented, evaluated and revised over time. All of these elements are essential for a nuclear weapons programme, and their absence or gradual withering away as a result of the decision not to replace the RAF’s nuclear capability offers important insights into what effective national denuclearisation will likely entail. That such a material, institutional and ideational infrastructure is required should not be surprising. In his magisterial account of how Britain organised itself to fight and ultimately win the Napoleonic War, Roger Knight noted inter alia that,

---

[3] This is discussed in detail in Nick Ritchie (2023). Irreversibility and Nuclear Disarmament: Unmaking Nuclear Weapon Complexes. *Journal for Peace and Nuclear Disarmament*, 6:2, pp. 218-243.
[4] The issues under discussion here would be similar in the context of the denuclearisation of the Royal Navy’s tactical nuclear weapons role when it gave up carrying WE177s on its surface ships.

> ‘The foundations of military victory, though, lay in the industrial capacity of cannon-founders, the expertise of gunsmiths in their machine shops, the diligence of shipbuilders and the makers of ropes, uniforms, gun-carriages and gunpowder … In turn, none of this could have been achieved without the men who signed and passed contracts across tables in government departments, the civil servants who drafted documents and did sums in the backrooms and basements of Whitehall …’[5]

Knight’s essential thesis is that success was down to the detailed technical and often unglamorous end of things – as one can see from the list of activities and capabilities he provides here. In short, an effective military operational capability is more than just soldiers and guns. We can perhaps transpose this concept when looking at the RAF’s WE177 programme and in examining its constituent elements we see that it was not just the simple fact of the withdrawal and dismantlement of the RAF’s stock of WE177A, B and C weapons that enabled the RAF’s ultimate denuclearisation. There was more to it than that.

[5] Roger Knight (2013). *Britain Against Napoleon The Organisation of Victory 1793-1815*. Allen Lane, Penguin, London. Kindle version location 80955.

1. A nuclear RAF and the WE177 'ecosystem'

There were many attributes required to sustain the RAF's nuclear role, and by implication their withdrawal, dismantlement, reassignment, disbandment or abandonment whether immediate or gradual would inevitably mean a loss of that capability. An operating framework that assembled these essential attributes consisted of the following essentials:

Weapon system:

1. A safe and reliable nuclear warhead, ballistic casing, and integrated arming, fuzing and drogue systems, as well as a system/facility for refurbishing the warhead.
2. Aircraft assigned a nuclear role, and therefore wired for nuclear weapons carriage/appropriate avionics and certified to carry such weapons after flight and carriage testing.
3. Weapons engineering companies (Hunting Engineering and prime contractor) for ensuring maintenance and refurbishment of WE177 non-nuclear components and providing 'Post Developments Services' to the RAF in support of keeping the WE177 serviceable.

Training:

4. Training and inert rounds for training purposes such as ground crew handling and loading on aircraft or target practice for aircrew.
5. Surveillance rounds for assessing safety and reliability of warheads in long term storage and operational conditions such as carriage in bomb bays of aircraft flying in prolonged humid or sub-arctic conditions, and an extensive programme of flight trials as part of the weapon's surveillance and life Evaluation Programme all of which required personnel, equipment and facilities.
6. Trained and security vetted aircrew for nuclear assigned aircraft e.g. trained to fly the flight profiles for weapon delivery, and regular training programmes and flights to ensure capabilities.
7. Training materials (films, lecture notes, manuals) and instructors and training programmes for staff assigned nuclear weapon roles.
8. A programme of regular exercises to sustain operational capabilities and readiness.

Security:

9. Safe and secure certified specifically designed weapon transport containers (e.g. WE155) and trolleys for storage and movement of warheads between maintenance facilities and within the airfield as well as other support equipment.
10. Supplementary Storage Areas (SSAs) and/or Hardened Aircraft Shelter (HSA) vaults for secure and safe storage of nuclear weapons that meet established criteria of fencing (three lines, height and mesh size, number and placement of intruder alarms), floodlighting, watchtowers, locks, door thickness, guard forces (and Rules of Engagement), explosive storage licensing regulations, and guard and maintenance staff for such facilities.

11. Trained and security vetted ground crew such as armourers and weapons engineers for loading weapons to aircraft and safe movement between storage areas to airfield hardened aircraft shelters.
12. Transportation vehicles for warhead transport convoys to and from AWE Burghfield and SSAs along with practiced standard operating procedures (SOPs) for their deployment/movement, and a management structure to plan and implement maintenance schedule.
13. Emergency response capability for nuclear accidents and procedures for dealing with accidents or near misses involving either movement, handling or storage of weapons. Some of this would be unique to the RAF, but would be relevant for all UK nuclear weapons.

Command and control and doctrine:

14. RAF Strike Command/MOD Air Staff for targeting plans, national command authority chain for authorisation to use nuclear weapons; management for nuclear role aircrew and ground crew, weapons movement and for ensuring operational force available, and policy branches/divisions within Strike Command/Air Staff MOD.
15. SOPs for safe and secure weapons handling whilst in RAF custody, which were voluminous.

These can be organised into five broad categories that are discussed in detail below: 1) Weapon system; 2) Doctrine, command and control; 3) Training; 4) Security; and 5) Safety.

Weapon system

Development, testing and manufacture

Approximately 270 WE177s of three variants were manufactured between 1966 and 1977: WE177A with variable yield of 0.5-10 kt deployed on Royal Navy aircraft and helicopters; WE177B with a yield of 450 kt was initially deployed on RAF Avro Vulcan bombers; WE177C with a yield of 190 kt deployed at RAF airbases in Germany on Jaguar and later Tornado aircraft.[6]

A network of organisations was required to design, test and manufacture the weapons. The weapon required development, testing and certification of a safe and reliable nuclear warhead, a ballistic casing for the bomb, and a host of non-nuclear sub-systems. The Atomic Weapons Research Establishment (AWRE) at Aldermaston developed the warhead design through a series of explosive nuclear tests at the Nevada Test Site under the auspices of the 1958 US-UK Mutual Defence Agreement.[7] AWRE manufactured the fissile material components, with final weapon assembly taking place at the Royal Ordnance Factory (ROF) Burghfield.

[6] John R. Walker (2018). A History of the United Kingdom's WE 177 Nuclear Weapons Programme: From Conception to Entry into Service 1959-1980' *BASIC*, London, p. 31.
[7] Walker. 'A History of the United Kingdom's WE 177', p. 10.

Contracts with commercial or other state entities were required to build specific facilities and manufacture complete weapons or their components. The co-ordinating design authority and design of the non-nuclear components for the WE177 was given to Hunting Engineering Ltd. Irving Ltd designed and developed the quadruple parachute assemblies used to retard the weapon on release, whilst Thorn-EMI Defence Electronics designed and developed the radar fuse. The Airfield Radio Laboratory (ARL) at the Royal Aircraft Establishment (RAE) Farnborough was lead design authority for the ballistic casing.[8] There were over 400 specifications for the non-nuclear components all of which had to be drafted, checked and signed-off and followed in manufacturing instructions.[9] Quality assurance and quality control is thus a critical element in the series production of weapons for service use.

The weapon underwent around 400 trials to test the functioning and safety of the weapon system in operational environments before acceptance into service by the RAF and RN. This included extensive trials to test the effects of temperature on the weapon in a broad set of scenarios, for example high temperatures whilst loaded on planes waiting on airfields. Trials were conducted at AWRE's Impact Facility at Orford Ness in Suffolk, the rocket range at West Freugh in south–west Scotland, and the Aeroplane and Armament Experimental Establishment (AAEE) Boscombe Down in Wiltshire.[10] This included ground initiation trials, fuze trials, flight trials and parachute release trials.[11]

Surveillance and evaluation

An in-service surveillance and life evaluation programme was necessary to ensure the weapon remained reliable, safe and fit for operational service conditions. Regular and extensive safety and reliability trials were conducted on a range of components to maintain quality assurance using surveillance rounds. These were identical to a live weapon but with fissile material components replaced by depleted uranium and inert substances.[12] Periodic weapon refurbishment was required given the limited shelf life of some components.[13]

The companies involved in production were also intimately involved in post-design and in-service maintenance and refurbishment of the weapons and therefore had facilities staff fully or partially dedicated to this role. Hunting Engineering Limited was responsible for structural, environmental and general issues, Pye Dynamics Limited dealt with the weapon fuzing, Marconi for the radar aspects and the Royal Armament Research Development Establishment at Fort Halstead for conventional explosives.[14]

AWRE Aldermaston refurbished the stockpile at a rate of about one tenth of the stockpile per year. This 'trickle philosophy' of continuous refurbishment at the lowest meaningful

---

[8] Walker. A History of the United Kingdom's WE 177, p. 11.
[9] Mike Fazackerley (2006). Unpublished paper. 'Bomb WE177 and D.A, Bateman, Farnborough's Involvement in the Development and Delivery of Nuclear Weapons, 3 March 1999'. Presented at a Mountbatten Centre UK Atomic History Seminar 2006.
[10] Walker. A History of the United Kingdom's WE 177, p. 12.
[11] Walker. A History of the United Kingdom's WE 177, p. 11.
[12] Walker. A History of the United Kingdom's WE 177, p. 24.
[13] Walker. A History of the United Kingdom's WE 177, p. 24.
[14] Walker. A History of the United Kingdom's WE 177, p. 24.

rate was meant to ensure that facilities and expertise were exercised and manufacturing processes for life-limited components were sustained.[15] This was a complex process that "required careful planning, extensive industrial and engineering support networks, and a trials programme to sustain the WE177 in service as an operational weapon for both the RAF and the Royal Navy. This is a key feature of a nuclear weapons programme and has a significant footprint".[16]

Strike aircraft

The WE177 was deployed to a number of RAF airbases in the UK and overseas in specially constructed Supplementary Storage Areas (SSAs). These included Cottesmore, Honington, Marham, Scampton and Waddington in the UK; Bruggen and Laarbruch in Germany from 1973; and Akrotiri in Cyprus until 1975.[17] The RAF had several different types of aircraft certified to carry the WE177 over the years that the weapon was in service; the Vulcan B2, which was assigned to carry the WE177B but withdrawn in 1982, the Buccaneer (withdrawn March 1994), the Jaguar (withdrawn 30 April 2007) and the Tornado IDS. The RN also deployed the WE177 on the Sea Harrier FRS1 and Wasp, Wessex, Lynx and Sea King helicopters.[18] Strike aircraft had been designed from the outset to be dual-capable aircraft (DCA) capable of deploying nuclear and conventional weapons. By the time the final WE177A was withdrawn in 1998, the Tornado was the last dual-capable aircraft still in service. The Tornado continued in front line service until 1 April 2019. We assume that the dual-capable aircraft had the nuclear weapons-related arming and fuzing and associated electronic circuitry removed or disabled.

Nuclear doctrine, command and control

NATO doctrine

A military doctrine, strategy and concept of operations are required to make sense of any new weapon system in terms of how, why, where, when and by whom the weapon system is intended for use. NATO was the foundation of UK defence during the Cold War and NATO nuclear doctrine and strategy provided the framework for making sense of the deployment and potential use of the WE177. The key document for this period was MC 14/3 in 1967 on 'The Overall Strategic Concept for the Defence of the NATO Area'.[19] More detailed guidance was set out in the 'Provisional Political Guidelines for the Initial Defensive Tactical Use of Nuclear Weapons by NATO' (PPGs) in 1969.This was updated in 1986 with the 'General Political Guidelines for the Employment of Nuclear Weapons in the Defence of NATO' (GPGs). These guidelines stated that nuclear weapons should be used first by NATO, if necessary, even against a conventional attack in order to terminate the war.[20]

---

[15] Walker. 'A History of the United Kingdom's WE 177', p. 27.
[16] Walker. 'A History of the United Kingdom's WE 177', p. 28.
[17] Walker. 'A History of the United Kingdom's WE 177', p. 21.
[18] Walker. 'A History of the United Kingdom's WE 177', p. 20.
[19] Available at <https://www.nato.int/docu/stratdoc/eng/a680116a.pdf>.
[20] Beatrice Heuser (1995). The Development of NATO's Nuclear Strategy. *Contemporary European History*, 4:1, p. 47.

NATO/UK command structure

UK strike aircraft deploying the WE177 were integrated into the joint air and land battle plans of NATO under the command of SACEUR (Supreme Allied Commander Europe) with the exception of strike aircraft deployed to RAF Akrotiri in support of the Central Treaty Organisation (CENTO).[21] UK-based strike squadrons were controlled by UK Strike Command headquartered at RAF High Wycombe.[22] RAF Germany (RAF(G)) strike squadrons were under the operational control of SACEUR and formed part of NATO's 2ATAF (Second Allied Tactical Air Force), which was part of Allied Forces Central Europe (AFCENT) northern region command. 2ATAF was always commanded by a British officer.[23]

RAF(G) squadrons operated at 15 minutes' Quick Reaction Alert (Nuclear) (QRA(N)) until 1986 when the practice was ended following the US-Soviet summit in Reykjavik between Presidents Reagan and Gorbachev.[24] QRA required a larger number of aircraft and crews to sustain than UK-based units, which did not operate a QRA posture.[25] In one interviewee's experience, command and control through NATO was a complicated business for DCA with complex release procedures compared to the more straight-forward process for SSBNs.[26]

Assured communication

The RAF used mobile satellite links for use with the Skynet IV military communications satellites operated on behalf of the Ministry of Defence. These provided direct communications between Strike Command and RAF operational units within NATO and were specifically intended for secure communications such as requests for nuclear release.[27]

Organisational structure

There were departments responsible for the operation, planning and maintenance of the RAF's nuclear role in Strike Command and MOD Air Staff. These may have included parts of the bureaucratic structure working exclusively on nuclear issues, or would likely have had other responsibilities too, such as Assistant Chief of the Air Staff (Operational Requirements), Assistant Chief of the Air Staff (Operations) or Director Operational Requirements 1 (RAF) and Director Mechanical Engineering 2 (RAF) in the MOD. For example, it is not clear whether the post of Deputy Director Operational Requirements or Director Air Armament existed for purely nuclear matters; it is clear though that Air Member for Supply and Organisation (AMSO) included responsibility for the SSAs by the 1980s, but evidently its remit extended much wider inside the RAF.

---

[21] Shaun Gregory (1996). *Nuclear Command and Control in NATO: Nuclear Weapons Operations and the Strategy of Flexible Response.* Macmillan, Basingstoke, p. 120. CENTO was dissolved in 1979.
[22] Gregory. *Nuclear Command and Control,* pp. 53-56.
[23] Gregory. *Nuclear Command and Control,* pp. 121.
[24] Michael Napier (2017). *Tornado GR1 An Operational History*. Pen and Sword Books, Barnsley, p. 68.
[25] Napier. *Tornado* GR1, p. 44.
[26] Interview#9.
[27] Gregory. *Nuclear Command and Control,* pp. 123.

Training

Strike aircraft training

Operating a nuclear weapons capability safely and securely whilst ensuring the weapons can be detonated when and where required requires extensive training. This means training programmes, trainers, training facilities, testing and evaluation. Tornado air crews were trained at the Tri-National Tornado Training Establishment (TTTE) at RAF Cottesmore in Rutland. Pilots received four weeks of training on the ground, followed by nine weeks in the air. RAF pilots in the UK were trained in a 'hi-lo-hi' attack mode to fly high towards the intended target, then low to avoid radar detection and anti-aircraft missiles before dropping their WE177 payload on their single target and returning to high altitude for the return flight. Nuclear strike aircraft based in Germany were trained in a 'lolo-lo' mode to fly low from take-off to avoid radar detection and anti-aircraft missiles from the outset.[28]

TACEVAL

Tornado squadrons were subject to rigorous training evaluations, notably the annual Tactical Evaluation (Taceval). Tacevals were carried out by Strike Command in the UK and Commander Allied Air Forces Central Europe (COMAAFCE) in Germany. They tested every aspect of the unit's preparedness for war. Units were required to demonstrate they could generate the assigned number of armed aircraft and crews without notice and within strict time limits (Taceval Part I) and that the squadron could continue to operate effectively in Nuclear, Biological and Chemical (NBC) environments and under conditions of damage to the airfield (Taceval Part II). Maintenance crews and weapon loading teams were watched closely and flying sorties were 'chased' by Taceval evaluators. In addition, units faced a 'Mineval' station-run exercise each month and 'Maxeval' exercises run by external evaluators prior to a Taceval. Exercises concentrated on perfecting nuclear strike procedures, including operating from newly-built hardened aircraft shelters (HAS) at Honington and Marham, and command and control in NBC conditions when personnel would be scattered in concrete bunkers across an airbase.[29]

In Germany, Mineval, Maxeval and Taceval exercises called QRA crews immediately to cockpit readiness within the NATO-approved minimum time.[30] NATO TACEVALs presented a unit with an integrated operations, logistics, and Survive to Operate (STO) conventional or NBC scenario to demonstrate its declared capability.[31] Aircraft generated in a strike role had live nuclear weapons loaded after which aircraft would be reconfigured with training weapons and a flying phase initiated. Tacevals were usually performed with full NBC protective equipment outside of any hardened and filtered accommodation.[32] Air Commodore P J Wilkinson writes that "TACEVAL, and all the lower level alert and

---

[28] Gregory. *Nuclear Command and Control,* pp. 122.
[29] Napier. *Tornado* GR1, p. 26.
[30] Napier. *Tornado* GR1, p. 49.
[31] Lt Col Jeffrey L. Hoing (2003). Evaluating Operational Readiness for Fixed-Wing Tactical Aviation Units. School of Advanced Military Studies United States Army Command and General Staff College Fort Leavenworth, Kansas. Citing Supreme Allied Commander, Supreme Headquarters Allied Powers Europe, ACE Forces Standards (AFS), vol. 6, SHAPE Tactical Evaluation Manual (STEM) (Brussels, Belgium: North Atlantic Treaty Organization, 9 April 2002), pp. 1-12.
[32] Tom Eeles (2021). 'The Buccaneer's Nuclear Bite'. 4 March. *Aeroplane Magazine* <https://www.key.aero/article/buccaneers-nuclear-bite>.

readiness tests, kept the edge permanently sharpened".[33] UK strike squadrons also took part in large scale exercises, such as NATO's annual Exercise Central Enterprise over Europe, the USAF Strategic Air Command (SAC) Bombing Competition known as Exercise Prairie Vortex, and annual Exercise Mallet Blow over the UK.[34]

Armament Support Unit

Training and testing facilities for armed forces personnel on the handling, storing, movement and loading of new weapons was originally provided by the RAF Bomber Command Armament School (BCAS) at RAF Wittering. It was formed to provide armament training and technical support to ground crews for the V-Bombers. BCAS later became the RAF Armament Support Unit as the instructional and standardisation unit for nuclear weapons procedures. All crews were subject to a thorough annual inspection by an Air Force Department Weapon Standardisation Team (AFDWST) from the unit. The AFDWST inspected all RAF activities associated with nuclear weapons including: land transport (convoys), air transport, base storage, and operational deployment of training rounds. The unit inspected safety, security and operational reliability procedures, spending. one to two weeks at a base.[35] It was independent of the RAF operational command structure and a failed inspection was extremely serious and would result in an instant posting away to a non-strike station.[36] The unit disbanded in 2002, four years after the last WE177 was withdrawn from operational service. The WST system was enormous, but there were still accidents.[37]

The RAF Armament Support Unit's Training Squadron provided initial training for all engineering tradespeople and aircrew for the strike role.[38] Ground crew were trained rigorously for strike operations. This encompassed weapon loading teams, armament electricians and the aircraft handlers who would have to maintain the strike-loaded aircraft. Every six months the armament electrical system on each strike aircraft had to be recertified. This required the Unit Certifying Officer (UCO) to supervise electrical tests of the installation having first examined every job card raised over the last six months to check that all work carried out on the aircraft had been completed by authorised and qualified electrical tradesmen.[39] The training of the weapon load teams was carried out at the Armament Training Cell in the Armament Engineering Squadron of Engineering Wing. The accuracy of the UCO's work was checked annually by the Weapon Standardisation Team. If a load team or UCO failed the check they were decertified immediately.[40]

---

[33] Royal Air Force Historical Society (1999). Royal Air Force In Germany 1945-1993. *Royal Air Force Historical Society Journal* 22, p. 76. <https://www.rafmuseum.org.uk/documents/research/RAF-Historical-Society-Journals/Journal-22A-RAF-in-Germany.pdf>.
[34] Napier. *Tornado* GR1, pp. 28-39.
[35] Sir Ronald Oxburgh (1992). The Safety of UK Nuclear Weapons. Ministry of Defence Chief Scientific Advisor. Annex B.
[36] Napier. *Tornado* GR1, p. 50.
[37] Presentation by Mike Fazackerley. RAF Bruggen: Accident involving WE.177 free-fall nuclear bomb, 1984. Charterhouse, 2023.
[38] Royal Air Force Historical Society (2001) The RAF and Nuclear Weapons 1960-1998. *Royal Air Force Historical Society Journal 26,* p. 85.
[39] Ibid., p. 89.
[40] Ibid., p. 89-90.

Security

Secure weapon facilities

In 1987, the US, and then NATO, began installing Weapons Storage and Security Systems (WS3) vaults at all major European airbases. This allowed nuclear weapons to be stored underneath an aircraft in a vault constructed into the floor of a n HAS. 215 WS3 vaults were built in Europe plus an additional 10 at RAF Brüggen and 24 at RAF Marham for WE177 bombs.[41] Each 'live' HAS at Brüggen and Laarbruch had a Tornado loaded with the WE177 with air and ground crews at 'crew room readiness' in a hardened shelter.[42] Physical access to WE177s was controlled through the provisions of Secret Document 814 (SD814) which included a 'No Lone Zone' and '2-man principle' around the weapon and detailed arrangements for transfer of custodianship from storage. This meant "everyone in the vicinity of the weapon had to be accompanied by someone with appropriate training so that incorrect actions could be spotted immediately. On completion of the load the aircrew allocated to the mission would be taken to the HAS to accept the aircraft and custody of the weapon".[43]

RAF Police and base protection

HAS were guarded by RAF Police. Weapons could not be brought onto the squadron site until it had been designated as a Follow-On Area (FOA). This required the presence of RAF Police, restriction of access to the site to named individuals, guards to be live-armed and mobile security patrols within the site.[44] There was a considerable effort put into ensuring that the RAF Police had the manpower and policies/procedures for ensuring weapon security, including frequent exercises and reviews of posture and performance. However, interviewees reported ongoing challenges with recruitment and retainment of security personnel due to poor pay and working conditions and low morale.

Weapon transport and protection

The Armament Support Unit was also responsible for the safe transport of nuclear weapons for both the RAF and RN using bespoke weapon transport vehicles that met specific security standards.[45] Weapons were also transported between RAF(G) bases and AWRE by Hercules aircraft, which could carry up to 6 containerised bombs at a time.[46]

Interviewees recalled that managing nuclear weapons on base was a huge undertaking for armourers and ground crews.[47] Whole regiments of the RAF were deployed to protect nuclear weapons.[48] Protecting nuclear air bases was a significant undertaking in terms of fixed infrastructure, number of people, training and competence and evaluation, with

---

[41] Otfried Nassauer, Oliver Meier, Nicola Butler & Stephen Young (1997). US nuclear NATO arsenals 1996–97. *BASIC Notes*, 7 February <https://basicint.org/wp-content/uploads/2018/06/PUB010297.pdf >; Robert Norris and Hans Kristensen (2004). U.S. nuclear weapons in Europe, 1954–2004. NRDC Nuclear Notebook. *Bulletin of the Atomic Scientists* 60:6, pp. 76-77.
[42] Napier. *Tornado* GR1, p. 44.
[43] The RAF and Nuclear Weapons 1960-1998, p. 91.
[44] The RAF and Nuclear Weapons 1960-1998, p. 91.
[45] Oxburgh. The Safety of UK Nuclear Weapons, p. 18.
[46] Fazackerley. RAF Bruggen: Accident involving WE.177 free-fall nuclear bomb.
[47] Interview#2.
[48] Interview#9.

challenges of retention and recruitment. Transport security was manpower intensive requiring specialist vehicles and containers. Everyone who tended to the weapons and aircraft - air crew, technicians, armourers, ground crew - were heavily guarded by armed police. Certifying assurance of weapons system integration into the aircraft was very complex.[49]

Safety

The 1992 'Report on the Safety of Nuclear Weapons' chaired by Chief Scientific Advisor Professor Sir Ronald Oxburgh set out in detail the policy organisations and committees involved in managing safety and security within the nuclear weapons enterprise. Much of this institutional infrastructure continues today in various forms to manage the current nuclear weapons complex centred on the Holbrook warhead and Trident II D5 SLBM.

Nuclear weapon safety organisation

Within MoD, Assistant Chief of Defence Staff (Policy and Nuclear) (ACDS (Pol&Nuc) was the primary operational policy lead who answered to the Deputy Under Secretary (Policy). Specification of physical protection and technical security measures associated with nuclear weapons was provided by the Directorate of Nuclear Policy and Security (D Nuc (Pol/Sy)) within the Defense Staff.[50] The Nuclear Weapons Safety Committee (NWSC), which comprised security-cleared academics and industry experts, provided independent advice to the Secretary of State for Defence on safety matters pertaining to all aspects of nuclear weapons from design through to operations.[51]

The Ordnance Board (OB) was central. It was responsible for the safety of all munitions, established design safety principles for weapons systems and stores containing explosives, and examined any warhead proposal a number of times in its evolution. It examined "nuclear warheads and weapons and their associated servicing, support and test equipment, during development and in service. Where nuclear warheads are fitted, the safety of aircraft weapon control and release mechanisms and missile delivery systems. The assessment of safety and suitability for service of road vehicles and transport aircraft for the carriage of nuclear warheads and weapons".[52]

The Warhead Safety Coordinating Committee (WSCC) within AWE and chaired by AWE's Safety Director provided advice to AWE's Chief Executive who had the responsibility for certifying to the Procurement Executive (PE) the performance and safety characteristics of the warhead.[53] An interdepartmental Explosive Storage and Transport Committee (ESTC) sponsored by MoD was responsible for classifying military explosives and prescribing the standards of safety for use throughout MoD during the storage of military explosives and regulating their conveyance. The Deputy Under Secretary (Personnel and Logistics) was the responsible authority. The committee was chaired by the Director of Defence Health

[49] Interview#3.
[50] Oxburgh. The Safety of UK Nuclear Weapons, p. 25.
[51] Oxburgh. The Safety of UK Nuclear Weapons, p. 16.
[52] Oxburgh. The Safety of UK Nuclear Weapons, Annex B.
[53] Oxburgh. The Safety of UK Nuclear Weapons, p. 16.

and Safety accountable to the 2nd Permanent Under Secretary through the General Health and Safety Policy Committee.[54]

Nuclear accident response

Nevertheless, accidents involving WE177s still occurred.[55] The RAF Armament Support Unit was responsible for nuclear accident response until 1987, when responsibility was transferred to a new Nuclear Accident Response Organisation (NARO) under the Assistant Chief of Defence Staff (Policy & Nuclear) (now called the Defence Nuclear Emergency Organisation). One interviewee described this as an army of people still largely run by the RAF because it was considered more likely to have an accident than the Royal Navy.[56] Scenarios included: nuclear weapon storage handling or transport accidents; naval nuclear reactor accidents at berth or at sea; nuclear material transport accidents involving plutonium, highly-enriched uranium, tritium or depleted uranium; contractor licensed site accidents involving naval reactor or nuclear weapons components or materials; used reactor fuel transport accidents; naval reactor neutron source transport accidents; depleted uranium munition accidents.[57]

[54] Oxburgh. The Safety of UK Nuclear Weapons, Annex B.
[55] Known accidents include: Two torpedoes falling on to a WE177 on board HMS Tiger in Malta in 1974; a WE177 dropped while loading on to an aircraft at RAF Laarbruch, Germany in 1974; a WE177 falling off a workstand RAF Honington while being loaded onto a plane in 1976; a WE177 dropped at RAF Bruggen reportedly causing the base to shut for a period in 1984; 1987: a truck with two WE177s skidding and rolling on to its side and second truck sliding off road in Wiltshire in 1987; WE177 was dented after it was the dropping and denting of a WE177 at RAF Marham in 1988. Rob Evans (2003). MoD catalogues its nuclear blunders. *The Guardian,* 13 October <https://www.theguardian.com/environment/2003/oct/13/energy.nuclearindustry>. See Peter Burt (2020). Playing with Fire: Nuclear Weapons Incidents and Accidents in the United Kingdom. *Nuclear Information Service*, Reading, for details.
[56] Interview#9.
[57] TNA AIR 8/3882. Accident Scenarios Requiring a MOD NARO response. Annex A to A Critical Review of MOD's Nuclear Accident Response Organisation. 7 March 1994.

2. Undoing the WE177 ecosystem

The process of denuclearising the RAF unfolded in the early 1990s as the Cold War came to an end. Two factors drove the process: 1) the end of the Cold War; 2) the cost and difficulty of developing a WE177 successor. These two factors are relevant for understanding the practical irreversibility of the denuclearisation process because together they destabilised the 'nuclear RAF ecosystem' to the point where it could not sustain itself. In the end, the ability of the Trident D5 system to offer a sub-strategic role made it easier to give up plans for a new theatre nuclear warhead. It was also much cheaper and thus easier to accept.

Changes in nuclear doctrine

NATO sub-strategic nuclear doctrine

Denuclearising the RAF was not a deliberate strategy but a de facto development shaped by a set of technical, political and international conditions. The end of the Cold War, dismantling of the Warsaw Pact and dissolution of the Soviet Union meant that nuclear targets that needed to be held at risk in NATO plans disappeared. This undermined the rationale for an extensive NATO sub-strategic arsenal including an independent air-delivered UK sub-strategic capability.

This led to a major reduction in NATO nuclear forces and a shift away from a sub-strategic nuclear strategy based on holding at risk a specific target set, and towards a more adaptive approach labelled Allied Command Europe (ACE) Nuclear Contingency Options (ANCOs).[58] The 1967 MC 14/3 strategy document was superseded in November 1991 by a 'New Strategic Concept' that was set out in the still classified 'MC Directive for Military Implementation of the Alliance's Strategic Concept' (MC 400) and a new set of General Political Guidelines on the first use of nuclear weapons. These documents significantly reduced the role of sub-strategic nuclear weapons.

The New Strategic Concept stated that: "The circumstances in which any use of nuclear weapons might have to be contemplated by them [the Allies] are therefore even more remote. They can therefore significantly reduce their sub-strategic nuclear forces. They will maintain adequate sub-strategic forces based in Europe which will provide an essential link with strategic nuclear forces, reinforcing the trans-Atlantic link. These will consist solely of dual capable aircraft which could, if necessary, be supplemented by offshore systems. Sub-strategic nuclear weapons will, however, not be deployed in normal circumstances on surface vessels and attack submarines. There is no requirement for nuclear artillery or ground-launched short-range nuclear missiles and they will be eliminated."[59]

[58] TNA FCO 179/488. High Level Group Guidance to SACEUR on Stockpile Size and Composition - Methodology. Paper by the UK on Behalf of Quadrilateral Working Group. 22 February 1991.
[59] NATO (1991). The Alliance's New Strategic Concept, 8 November <https://www.nato.int/cps/en/natohq/official_texts_23847.htm>.

UK sub-strategic nuclear doctrine

In the UK, the Conservative government's 1990 'Options for Change' defence review set out an 18% reduction in armed forces and other measures to reduce the defence budget. However, even with the end of the Cold War, a UK sub-strategic force of dual-capable Tornados with a new stand-off missile to replace the WE1777 was still deemed necessary to provide a credible first-use threat as a hedge against a resurgent Soviet Union re-establishing conventional superiority in Europe. A new rationale also emerged that sub-strategic weapons could be used if "UK vital interests were in the future threatened by a 'third world' power' as a result of the proliferation of nuclear, chemical and biological weapons.[60] However, the reconfiguration of UK armed forces after the Cold War would, in the end, result in the termination of the RAF's nuclear mission.

Reductions in nuclear weapons

Major reductions in US and Soviet theatre nuclear weapons

The US and Soviet Union withdrew and cancelled a number of nuclear weapon programmes through the Presidential Nuclear Initiatives (PNIs) of September 1991 and January 1992.[61] The 1991 PNI announced the withdrawal and planned destruction of all 1,300 nuclear artillery shells and 850 short-range Lance missile warheads deployed abroad, withdrawal of all tactical nuclear weapons from surface ships, submarines and land based naval aircraft, and cancellation of the Short-Range Attack Missile II (SRAM-II) and its W98 nuclear warhead and Short-Range Attack Missile-Tactical (SRAM-T) and its W91 nuclear warhead.[62]

Withdrawal of WE177

In October 1991 the government announced its intention to reduce the stockpile of WE177 bombs by 50%. This was followed by a further announcement in June 1992 that all naval theatre nuclear weapons would be removed from surface ships and aircraft. The government's intention at this stage was to continue with the WE177 carried by Tornado into the first few years of the 21st century. However, in April 1995 the government announced that the WE177 would be withdrawn from service by the end of 1998.[63] The last four WE177 weapons were convoyed out of Marham on 22 April 1998 drawing to an end one of the RAFs most significant post-war tasks.[64] All the weapons were dismantled by August 1998[65] and fissile material recovered from dismantled WE177 warheads was retained for defence purposes.[66]

---

[60] Tom King, (1990). Defence (Options for Change). *House of Commons* HC Deb (*25* July 1990) vol. 177 col. 468-86; TNA DEFE 25/812. UK Sub-Strategic Nuclear Capability. Draft letter from PS/S of S to PS NO 10 containing a paper on the Rationale For UK Sub-Strategic Capability. 22 October 1991.
[61] Stephen Cain (1990). Just a Trim Please. *Bulletin of the Atomic Scientists,* 46:3.
[62] Full details of both PNIs and details of the reciprocal reductions by Gorbachev and Yeltsin are set out in Richard B. Cheney (1992). *Prepared Statement by Richard B. Cheney, Secretary of Defense,* Hearing before the Senate Committee on Armed Services 'Military implications of START I and START II'. July 28. United States Senate, Washington, D.C.
[63] Nicholas Soames, (1995). 'Sub-Strategic Nuclear Capability'. House of Commons HC Deb (4 April 1995) vol. 257 col. 1095W; Secretary of State for Defence (1996). Statement on the Defence Estimates 1996. Cm 3223. p. 24.
[64] The RAF and Nuclear Weapons 1960-1998, p. 92.
[65] George Robertson, (1998). 'Warheads'. HC Deb (30 July 1998) vol. 317 col. 436-37W.
[66] Jonathan Aitken, (1992). 'WE 177 Bomb'. HC Deb (15 July 1992) vol. 211 col. 815W.

Drawdown of UK strike squadrons

This coincided with a major drawdown of UK strike squadrons and withdrawal of the RAF from Germany. The QRA mission for strike squadrons in RAF(G) had already ended in 1986. Options for Change in 1990 announced a halving of the Tornado force in Germany by disbanding the three Tornado strike/attack squadrons at Laarbruch the following year and redeploying II Squadron to Marham.[67] Laarbruch ceased to operate as an airbase for strike aircraft in 1991. Further reductions were announced in the 1998 Strategic Defence Review. By the end of the decade five Tornados squadrons remained, six had been disbanded, and by 2002 the RAF had completely withdrawn from Germany.[68] The 1998 Strategic Defence Review confirmed that the new Eurofighter Typhoon would replace front-line Tornado aircraft and would not be nuclear-certified. The major upgrade of the Tornado in the mid-1990s to the GR4 after the withdrawal of the WE177 was a complete rebuild and nuclear wiring enabling nuclear release was probably stripped out.[69]

In 1991 UK Tornados deployed to Bahrain and participated in the Gulf War as part of Operation Granby, highlighting the importance of the Tornado's conventional attack capabilities at a time when the viability of its nuclear strike role was diminishing with the dissolution of the Warsaw Pact, the reunification of Germany, and former Warsaw Pact states keen to join NATO.[70]

Ending the training regime and RAF nuclear organisation

Once the decision had been made to end the RAF's nuclear role and the last squadron at RAF Marham saw its last WE177As head off to AWE Burghfield for dismantlement, there was no further requirement for training squadrons for a nuclear role. The last formal training course for RAF aircrew training with the WE177 took place in April 1997 with simulator training continuing until March 1998.[71] Both aircrew and ground crew would have been assigned to other posts or would have left the RAF as a period of reductions in its overall size, staffing and budget followed. For example, an assessment in May 1994 stated that withdrawal of the WE177 would result in savings of £2.5 million in RAF training and support costs.[72] Although the Tornado aircraft continued in service following the withdrawal of the last WE177s in 1998, the numbers of personnel trained and exercised for a nuclear role would have diminished to a point where there would eventually be no one serving in the RAF in any position with experience or memory of the nuclear role. This could perhaps be a period of up to twenty years, for example a Tornado pilot aged 28 in 1998 could go on to serve as an Air Vice Marshall in their late 40s.

In addition, the denuclearisation of the RAF would have led to both the disappearance of nuclear weapons related responsibilities within departments and individual posts as well as their disbandment and reallocation of staff to other duties.

---

[67] Napier. *Tornado* GR1, p. 82.
[68] Tom Dodd and Mark Oakes (1998). The Strategic Defence Review White Paper. House of Commons Library, Research Paper 98/91, p. 42.
[69] Interview#3.
[70] Napier. *Tornado* GR1, p. 70.
[71] John Reid (1998). Written answers (Commons) of Monday 20 April 1998. 38959.
[72] TNA AIR 8/3882. WE177 - Weapon Storage Vaults. Annex A: Financial Implications of Early Withdrawal. 9 May 1994.

Table 1: Drawdown of UK strike squadrons[73]

Squadron	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
9 Tornado	BRG	BRG	BRG	BRG	BRG	BRG	BRG	BRG	BRG	BRG	MRM
14 Tornado	BRG	BRG	BRG	BRG	BRG	BRG	BRG	BRG	BRG	BRG	LSM
15 Tornado	LBH	*DIS*									
16 Tornado	LBH	*DIS*									
17 Tornado	BRG	BRG	BRG	BRG	BRG	BRG	BRG	BRG	*DIS*		
20 Tornado	LBH	*DIS*									
27 Tornado	MRM	MRM	MRM	LSM	LSM	LSM	LSM	LSM	LSM	LSM	LSM
31 Tornado	BRG	BRG	BRG	BRG	BRG	BRG	BRG	BRG	BRG	BRG	MRM
617 Tornado	MRM	MRM	MRM	MRM	MRM	LSM	LSM	LSM	LSM	LSM	LSM
12 Buccaneer	LSM	LSM	LSM	*DIS*							
208 Buccaneer	LSM	LSM	LSM	*DIS*							

BRG = Bruggen; LBH = Larbruuch; MRM = Marham; LSM = Lossiemouth; DIS = disbanded.

Airbase infrastructure

The SSAs and older nuclear weapons storage facilities at RAF stations were left to decay over time or transferred to the civil sector – as was the case for part of RAF Barnham and the whole of RAF Gaydon. Some were used as temporary storage sites for other purposes or just left empty with no attempt to maintain the support buildings or storage bunkers. The earthen revetments built around the bunkers were not maintained and have started to collapse in some cases. RAF Honington's SSA has been used for several arms control and disarmament verification exercises for Chemical Weapons Convention purposes and for nuclear disarmament research primarily because it provided a realistic setting for these exercises.

Replacing the WE177

Understanding the challenges of reversing the denuclearisation of the RAF can be enhanced by examining the aborted process to replace the WE177.

The case for a FTNW

In early 1980s MOD and NATO initiated processes to modernise NATO and UK TNW capabilities. NATO called for a Tactical Air-Surface Missile (TASM) to replace free-fall

[73] Based on 1990-1996 Statement on the Defence Estimates Annex C 'The Strength of the Royal Air Force'.

bombs by 1985[74] and in 1986 MOD's Theatre Nuclear Weapon Policy Steering Group (TNWPSG) recommended a variable-yield stand-off TASM with a range of 300-400 kms as a successor to the WE177.[75] A Future Theatre Nuclear Weapon (FTNW) programme was endorsed by Cabinet Committee MISC 7 (Ministerial Group on Nuclear Defence Policy) in 1987. This was set out in Staff Target ST(SA)1244 that was approved by the Secretary of State for Defence in 1988 authorising a Feasibility Study to assess and compare the cost and technical risk of off-the-shelf and collaborative options to meet the operational requirement.[76] In October 1990, the Equipment Policy Committee (Nuclear) (EPC(N)) endorsed Staff Requirement SR(SA)1244 for a FTNW with an in-service date of 2002, a decision supported by Cabinet Committee GEN 1 (formerly MISC 7) in December 1990.[77]

An in-service date of 1995 was preferred but 2001 was the earliest warhead production date AWE could meet after Trident.[78] AWE only had the capacity to design and develop one warhead at a time and Trident was the priority. Batches of WE177s would start to run out of serviceable life in 1996 and all weapons would be life-expired by 2007.[79] Despite major changes underway in Europe by 1990, an independent UK TNW was still considered essential in providing a link between conventional and strategic nuclear forces thereby preserving the credibility of the UK's nuclear threat and supporting NATO strategy.[80]

Missile options

The Feasibility Study led to the rejection of a cruise missile, free-fall bomb or the use of the Trident system to deliver a lower yield sub-strategic 'warning shot'.[81] The Special Systems Department at RAE Farnborough also studied two national delivery vehicle options: an air-launched stealthy cruise missile (ALSCM) and a medium range air-launched ballistic missile (MRALBM). Given the considerable technical, schedule and cost risk of either option, MISC 7 decided in 1988 to pursue a collaborative or off-the-shelf solution.[82] Initially the options were the Boeing Short Range Attack Missile (Tactical) (SRAM-T) and the Martin Marietta Supersonic Low Altitude Target (SLAT). The latter later became the Tactical Integrated Rocket Ramjet Missile (TIRRM) - a derivative of the SLAT. In 1989, a decision was taken to evaluate a French option following an offer from Paris to supply their

[74] TNA DEFE 25/711. FTNW - Politico-Military Factors. Annex S: Politico Military Factors. 4 September 1990.
[75] TNA DEFE 72/669. Chief Scientific Advisor. SR(SA) 1244 - Future Theatre Nuclear Weapon (FTNW). 2 November 1990.
[76] TNA DEFE 72/669. Future Theatre Nuclear Weapon. 2 November 1990. TNA DEFE 71/1286. Staff Target (Sea and Air) 1244: Air-Launched Theatre Nuclear Weapon. Two Star Draft. Annex D: Feasibility Studies. 7 April 1988. The Staff Target (ST) defines the military capability to be procured, followed by a Feasibility Study leading to a Staff Requirement (SR) defining in more detail the key performance and design features.
[77] TNA DEFE 25/812. Progress Report from CA to CSA on SR(A) 1244 Feasibility Studies and Risk Reduction (draft). 5 November 1991.
[78] TNA DEFE 72/669. MISC7 (90) 6. Cabinet. Nuclear Policy Committee. The Modernisation of the United Kingdom's Theatre Nuclear Weapons Capabilities, A Memorandum by the Secretary of State for Defence. (Draft). November 1990.
[79] TNA DEFE 25/812. UK Sub-Strategic Nuclear Capability. Draft letter from PS/S of S to PS NO 10 containing a paper on the Rationale For UK Sub-Strategic Capability. 22 October 1991.
[80] TNA DEFE 72/669. Future Theatre Nuclear Weapon. 2 November 1990; TNA DEFE 25/812. UK Sub-Strategic Nuclear Capability. Draft letter from PS/S of S to PS NO 10 on the Rationale For UK Sub-Strategic Capability. 22 October 1991.
[81] TNA DEFE 25/812. UK Sub-Strategic Nuclear Capability. Draft letter from PS/S of S to PS NO 10 containing a paper on the Rationale For UK Sub-Strategic Capability. 22 October 1991.
[82] TNA DEFE 71/1286. MoD Equipment Policy Committee ST(SA)1244 Future Theatre Nuclear Weapon. Fourth Draft. 7 April 1988.

existing ASMP stand-off missile or to collaborate on a derivative of the ASLP (Air-Sol Longue Portee), later referred to as ASLP-D2.[83]

SRAM-T was the cheapest option with lowest technical risk but at 250 kms it was short on range, accuracy and penetrability for which satisfactory solutions could not be identified.[84] TIRRM/SLAT had a range of between 520 and 700 kms with estimated in-service date of 2001-2. It was considered high risk in terms of cost and timescale, Because the missile was not required by the US as a tactical nuclear delivery system and would require substantial UK development expenditure to make it so, the UK would have to take on these risks alone.[85] Information on the US systems was provided to the UK under the terms of a special UK-US Memorandum of Understanding of 1 November 1988 on 'Co-operation on a Tactical Air-to-Surface Missile Feasibility Study'.[86] All visits associated with the discussion or transfer of information on warhead study, design, integration and interfaces would take place under the terms of the 1958 US-UK Mutual Defence Agreement (MDA). ASLP-D2 would be a joint development with France but in 1990 was still at the concept stage and unlikely to enter into service before 2003-5. Its range was estimated at between 760 and 980 kms but it was judged to be very high risk in terms of cost and timescale and it proved difficult to agree on a development programme.[87]

Integration with Tornado was complex and required a special weapon dedicated data bus because of the complicated relationship between stand-off weapon delivery accuracy, launch aircraft navigation performance, weapon range and weapon flight profile and any mid-course guidance system on the weapon.[88] The TIRRM option was the simplest solution, with SRAM-T and ASLP-D2 requiring a high-risk special offset launcher to allow weapon carriage on the nuclear-capable shoulder pylon stations under the wing, which could degrade Tornado's operational performance to an unacceptable level.[89] In addition, a new missile would require expensive training simulators and training equipment, including a ground trainer in launch procedures, training rounds suitable for ground handling and loading, drill/instructional rounds, and an airborne training device.[90]

Warhead options

Work on warhead design was the critical factor. Warhead feasibility studies assumed the new warhead would be interfaced with one of the three candidate missiles (SRAM-T,

---

[83] TNA FCO 46/7258. MISC7 (89) 7. Cabinet. Nuclear Defence Policy. The Modernisation of the United Kingdom's Theatre Nuclear Weapon Capabilities. Memorandum by the Defence Secretary. 12 December 1989.
[84] TNA DEFE 72/669. MISC7 (90) 6. Cabinet. Nuclear Policy Committee. The Modernisation of the United Kingdom's Theatre Nuclear Weapons Capabilities. Memorandum by the Secretary of State for Defence (draft). November 1990.
[85] Ibid.
[86] TNA DEFE 72/669. General Memorandum of Understanding between the Secretary of Defense of the United States of America and the Secretary of State for Defence of the United Kingdom of Great Britain and Northern Ireland Concerning The Acquisition by the United Kingdom of a Tactical Air-to-Surface Missile (draft). 30 October 1990.
[87] TNA DEFE 72/669. MISC7 (90) 6. Cabinet. Nuclear Policy Committee. The Modernisation of the United Kingdom's Theatre Nuclear Weapons Capabilities. Memorandum by the Secretary of State for Defence (draft). November 1990; TNA DEFE 71/1303. Progress Report from CA to CSA on SR(SA)1244 Feasibility Studies and Risk Reduction (draft). 10 October 1991.
[88] TNA DEFE 71/1303. Defence Research Agency, Royal Aircraft Establishment. Letter from D. Oxenham to C Edmunds. 2 September 1991.
[89] TNA DEFE 71/1303. Progress Report from CA to CSA on SR(SA)1244 Feasibility Studies and Risk Reduction (draft). 10 October 1991; TNA DEFE 71/1303. FTNW: Actions Placed at Follow-on DUS(P) Meeting. 24 September 1991.
[90] TNA DEFE 71/1286. Staff Target (Sea and Air) 1244: Air-Launched Theatre Nuclear Weapon. Two Star Draft. 7 April 1988.

TIRRM/SLAT, ASLP-D2).[91] Enough was known about each missile option in terms of the space available for a nuclear warhead to allow work to proceed for a period irrespective of the final choice of delivery system. However, delays to missile selection would cause delays in the warhead programme since each candidate missile presented different challenges in interfacing the warhead to protect it from environmental extremes and ensure proper operation.[92] The UK experienced similar problems when it was developing the Blue Steel stand-off missile in the late 1950s and early 1960s.[93]

The warhead was to be of variable yield ranging from the low to medium kiloton range[94] and AWE assessed three warhead design options: a Trident warhead derivative; the US W91 design for the SRAM-T; and a new warhead design. The Trident-derived option using SRAM-T electronics was judged technically inadequate, especially on safety[95] and it would not have the required variable yield.[96] Moreover, using Trident would not meet the requirement that initial nuclear use should be distinctly sub-strategic in nature and from a clearly identifiable source.[97] Manufacturing a US designed SRAM-T W91 warhead using US sub-systems would require substantial new investment in production facilities at AWE and cast doubt on the independence of a UK nuclear capability that underpinned the 1958 Mutual Defense Agreement. A UK design incorporating US SRAM-T electronics and sub-systems was therefore considered the Prime Option.[98] All three options relied on the availability of US components and technical cooperation under the 1958 MDA. Without it, the in-service date would be delayed by an estimated four years.[99]

US support for the UK's FTNW warhead design work ran through the Theatre Nuclear Weapon Interface Group (TWIG) after the necessary US Statutory Determination to authorise release of atomic information was signed in 1990[100] and an agreement was reached on a Use Control Group Charter.[101] Use control items are positioned critically in relation to the physics package in order to offer reliable operation and to guarantee safety

[91] TNA DEFE 72/669. The Impact on the Warhead Programme of a Delay in Vehicle Selection for FTNW. 5 December 1990.
[92] TNA DEFE 72/669. Future TNW: MISC 7 Paper (draft). 13 November 1990. The interface specifications on which the warhead design depends must be available at an early stage of the design process. Significant late changes to the warhead interface or environmental conditions after 'design chill', for example a result of missile selection, could extend development by two years and require significant redesign. The interfaces include a specification for mass and inertia together with mounting arrangements for the warhead which protect the sensitive physics package from environmental extremes and ensure proper operation. The interface description also includes electrical signal and power specification, vibration spectra and temperature data relevant to high-speed flight. TNA DEFE 72/669. The Impact on the Warhead Programme of a Delay in Vehicle Selection for FTNW. 5 December 1990.
[93] John R. Walker. (2010). British Nuclear Weapons and the Test Ban 1954-1973 Britain, the United States, Weapons Policies and Nuclear Testing: Tension and Contradictions. Farnham, Ashgate, pp. 60-61
[94] TNA DEFE 25/812. UK Sub-Strategic Nuclear Capability. Draft letter from PS/S of S to PS NO 10 containing a paper on the Rationale For UK Sub-Strategic Capability. 22 October 1991.
[95] TNA DEFE 72/669. MISC7 (90) 6. Cabinet. Nuclear Policy Committee. The Modernisation of the United Kingdom's Theatre Nuclear Weapons Capabilities. Memorandum by the Secretary of State for Defence. (draft). November 1990.
[96] TNA DEFE 72/669. SR(SA)1244: Future Theatre Nuclear Weapon. 2 November 1990.
[97] TNA DEFE 25/812. UK Sub-Strategic Nuclear Capability. Draft letter from PS/S of S to PS NO 10 containing a paper on the Rationale For UK Sub-Strategic Capability. 22 October 1991.
[98] TNA DEFE 72/669. SR(SA)1244: Future Theatre Nuclear Weapon. 2 November 1990.
[99] TNA DEFE 72/669. SR(SA)1244: Future Theatre Nuclear Weapon. 2 November 1990.
[100] TNA DEFE 72/669. SR(SA)1244: Future Theatre Nuclear Weapon. 2 November 1990. A Statutory Determination is a written determination by the President, or those duly authorised by the President, that the cooperation will promote and will not constitute an unreasonable risk to the common defence and security.
https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/503014p.pdf?ver=2018-11-14-144631-820.
[101] TNA DEFE 72/669. Warhead for FTNW: Discussions with US DOE. Deputy Controller (Nuclear). 9 January 1991.

over all operating conditions.[102] They are designed to prevent unauthorised use and to provide a command disable facility and an anti-tamper system.[103] UK systems were audited by the US to verify the UK's ability to manage very sensitive use control information.[104] AWE was keen to get access to US warhead design information as soon as possible. When they did, the warhead design information provided by US nuclear weapons laboratories to AWE was not as AWE had expected, and supporting US use control processes required changes to the UK's warhead design.[105]

Missile selection

MoD stated that the SRAM-T option was the most straight-forward case given the close relationship between the W91 and AWE Prime Option warhead design. TIRRM was likely to match closely the SRAM-T and both missiles could be tailored for carriage on the Tornado. Interfacing a new warhead with the French ASLP-D2 was the bigger challenge since the missile would need to be designed from scratch to accommodate the UK warhead and interface, based closely on the SRAM-T.[106] However, the Assistant Chief of Defence Staff Operational Requirements Air (ACDS OR(Air)) noted in July 1991 that the French did not respond positively to UK requests for additional cost and risk information for the ALPS-D2 programme and was "left with the impression that there is little intention on the part of the French to engage in serious dialogue on the question of requirement harmonisation or trade-off against our requirements".[107]

France offered to share its warhead design for the ASLP-D2 missile but MoD's Assistant Chief Scientific Advisor (Nuclear) considered this unacceptable given differences in manufacturing techniques, the UK's credibility as an independent nuclear-armed state, different safety regimes, and different nuclear testing sites and processes.[108] In addition, since the UK would remain reliant on the US for all warhead options, including a UK warhead for the ASLP-D2,[109] the US required assurances that sensitive warhead information would not be passed to France. Given the technical complexity of matching the warhead to the French missile, it would be difficult to ensure the missile's designers did not become aware of certain aspects of the warhead's design.[110]

The optioneering and design processes were thrown into disarray in 1991 when the US cancelled the SRAM-T programme as part of the PNIs. In addition, it had become clear by then that the ASLP-D2 would *not* be able to accommodate the UK's Prime Option warhead, that the French in-service date for the missile of 2010 was nine years after UK needs, and

---

[102] TNA DEFE 72/669. The Impact on the Warhead Programme of a Delay in Vehicle Selection for FTNW. 5 December 1990.
[103] TNA DEFE 25/812. UK Sub-Strategic Nuclear Capability. Draft letter from PS/S of S to PS NO 10 containing a paper on the Rationale For UK Sub-Strategic Capability. 22 October 1991.
[104] TNA DEFE 72/669. Minutes of the 2nd FTNW Management Meeting. 26 February 1991.
[105] TNA DEFE 72/669. The Impact on the Warhead Programme of a Delay in Vehicle Selection for FTNW. 5 December 1990.
[106] TNA DEFE 72/669. The Impact on the Warhead Programme of a Delay in Vehicle Selection for FTNW. 5 December 1990.
[107] TNA DEFE 71/1303. Anglo-French Nuclear Staff Talks. 15 July 1991.
[108] TNA DEFE 72/669. Future TNW: MISC 7 Paper (draft). 13 November 1990.
[109] TNA DEFE 72/669. SR(SA)1244 - Future Theatre Nuclear Weapon. 5 November 1990.
[110] TNA DEFE 72/669. Future Theatre Nuclear Weapon. 2 November 1990.

that there were significant compatibility issues with the Tornado GR4.[111] This left only an extended range TIRRM as a viable option.

Warhead work

The Cabinet Sub-Committee GEN 1 decision in December 1990 authorised AWE to begin work on the Prime Option warhead design based on a UK physics package incorporating enhanced safety features and with electronic and other sub-systems procured from the US W91 programme.[112] This 'Project Definition and Risk Reduction' phase was initially slow going because of delays in receipt of information from the US on the W91 warhead.[113]

Following cancellation of SRAM-T, the UK sought assurances on the status of the W91 but were told the programme was 'dead' and resources for it were being directed elsewhere.[114] The TWIG channel was time limited and once all W91 information had been transferred, it would be closed.[115] Nevertheless, there was some confidence that US work on the W89 warhead for the TIRRM would continue and the US expressed willingness to support the UK FTNW programme through the MDA's Joint Working Groups (JOWOGs).[116]

However, the UK's Prime Option warhead production programme set out in 1990 anticipated warhead 'design chill' in March 1993 followed by three underground project proofing tests in March 1995, September 1996 and September 1997 at the US Nevada Test Site, with production from 1998-2001.[117] The UK planned to conduct two technology tests at the Nevada Test Site in November 1991 and 1992. These were essential precursors to the planned series of three project proofing tests for the new warhead. The first of these was the BRISTOL test of a device (SUNBOW PRIME1) to support FTNW warhead development used new Insensitive High Explosive and improved fire resistance in a smaller and lighter device configured to fit in the US SRAM-T. An underlying objective of the BRISTOL test was to confirm the capability to achieve and understand the nuclear performance of a warhead design that was intended to be proof against the wide range of thermal conditions experienced by a theatre nuclear weapon, particularly when carried on an airborne missile.[118] SUNBOW PRIME 2 was planned for 1992, but was deferred for a year in response to pressures on the defence budget.[119] This delay appears to have

[111] TNA DEFE 71/1303. Anglo-French Nuclear Staff Talks. 15 July 1991; TNA DEFE 71/1303. FTNW: Actions Placed at Follow-on DUS(P) Meeting. 24 September 1991.
[112] TNA DEFE 71/1303. Progress Report from CA to CSA on SR(SA)1244 Feasibility Studies and Risk Reduction (draft). 10 October 1991.
[113] TNA DEFE 71/1303. Progress Report from CA to CSA on SR(SA)1244 Feasibility Studies and Risk Reduction (draft). 10 October 1991.
[114] TNA DEFE 71/1303. Fax from BDS Washington to AWE Burghfield, MOD UK and AWE Aldermaston. Subject: Status of SRAM T/W91 Programme. 29 October 1991.
[115] TNA DEFE 71/1303. Fax from BDS Washington to MOD UK and AWE Aldermaston. Subject: Status of W91 Programme and Statutory Determination (SD) and TWIG Channel. 28 October 1991.
[116] E.g. JOWOG 38 that shared information on battle modelling, computer simulations, war-gaming and other analytical activities designed To examine theatre nuclear weapon developments, new TNW concepts, technical investigations of problems associated with TNW deployment including safety, security, and survivability. TNA DEFE 71/1303. Operational Analysis for JOWOG 38. Annex A to D/ACDS (Pol&Nuc) 321/1/11/: JOWOG 38 – Scope. 26 June 1991.
[117] TNA DEFE 72/669. The Impact on the Warhead Programme of a Delay in Vehicle Selection for FTNW. 5 December 1990.
[118] TNA DEFE 19/588, Draft Minute from the Chief Scientific Advisor, MOD to the Secretary of State, UK Underground Nuclear Test, Bristol, 14 November 1991.
[119] TNA FCO 46/8048, Tom King, Secretary of State for Defence to Prime Minister, British Underground Nuclear Testing Programme,26 June 1990.

pushed back the FTNW project tests until 1997.[120] The UK planned a further test code named ICECAP for spring 1993, which would have completed the preparatory trials for the FTNW.[121]

The BRISTOL test was on the critical path for the FTNW. It was essential for the continued development of an entirely new warhead for the UK's tactical nuclear weapon to replace the WE177. The aim of the test was to build on the knowledge gained from two previous tests in December 1989 (BARNWELL) and November 1990 (HOUSTON).[122] The test would also complete the investigating phase of yield selection techniques. The UK FTNW, which would have been a development from the device tested in BRISTOL, was being designed to fit in any one of three FTNW systems under consideration.[123] The passing by the US Congress of the Nuclear Testing Moratorium Act in August 1992 and the extension of the testing moratorium by President Bill Clinton in 1993 ended all explosive nuclear testing at the Nevada Test Site including the UK's SUNBOW PRIME 2 test that was already in the works, severely complicating the FTNW warhead production process. A relevant lesson for the UK from the Chevaline programme was that developing a warhead without US support would entail considerably more expense and programme delays.

FTNW cancellation in favour of sub-strategic Trident

Concerns about the cost and difficulty of the FTNW programme began to gather pace. The UK Treasury was very concerned about the affordability of and requirement for a FTNW, in particular whether a UK FTNW was an *absolute* requirement[124] given that the US and NATO seemed satisfied with a NATO Dual Capable Aircraft (DCA) carrying US free-fall nuclear bombs.[125] Procuring the weapon would have significant opportunity costs in terms of conventional capability in the post-Cold War period.[126] In addition, the nuclear priority in government was managing the challenging transition from Polaris to Trident and the significant sums being invested in facilities at Coulport and Faslane under the Trident works programme, including the ship lift. Other concerns were raised about the vulnerability of strike aircraft and airfields, the support requirements for scarce air-to-air refuelling (AAR) assets, and increasing challenges of overflight rights from allies and former Warsaw Pact states. By this stage, the Tornado-WE177 weapon system was being described as 'largely ineffective and incredible' and sustaining a 'barely credible UK sub-strategic philosophy'.[127]

In addition, in 1991 the Royal Navy decided to opt out of the FTNW programme. ST(SA)1244 was originally for 'Sea and Air' (SA) and was co-sponsored by the RAF and

[120] TNA DEFE 19/588, John Mabberley, Deputy Controller (Nuclear), MOD to Mr K. Johnston, Director R&D, AWE Aldermaston, Nuclear Test Programme, 14 November 1990.
[121] John R. Walker (2023). *British Nuclear Weapons and the Test Ban Squaring the Circle of Defence and Arms Control 1974-1982*. Abingdon, Routledge, 126.
[122] TNA DEFE 19/588, J.A. Davies, Sc (Nuc)/1, MOD to PS/CSA, UK Underground Nuclear Test - Bristol, 1 October 1991.
[123] TNA DEFE 19/588, draft letter or CSA to send to the Secretary of State, under cover of a minute form J.A. Davies, Sc (Nuc)1, MOD to PS/CSA, UK Underground Nuclear Test – Bristol, 3 October 1991.
[124] TNA DEFE 25/812. UK Sub-Strategic Nuclear Capability. 24 October 1991.
[125] TNA DEFE 25/812. UK Sub-Strategic Nuclear Capability. 25 October 1991.
[126] TNA DEFE 25/812. UK Sub-Strategic Nuclear Capability. 25 October 1991.
[127] TNA DEFE 25/812. UK Sub-Strategic Nuclear Capability. 25 October 1991.

Royal Navy.[128] Avionics for FTNW were designed to be compatible with Tornado GR4, but also with Navy's Sea Harrier FRS2, Harrier GR5, Buccaneer replacement and Nimrod MR2 replacement aircraft, if possible.[129] The Navy ceased expenditure on its component of FTNW as a savings measure and all maritime references to FTNW were removed.[130]

In November 1991, the Assistant Chief Scientific Advisor (Nuclear) (ACSA(N)) wrote that both MOD's Chief Strategic Systems Executive (CSSE) and the Assistant Chief of the Naval Staff (ACNS) were promoting an argument that Trident could be used sub-strategically: Trident warheads could be set for ground burst as well as low, medium and high airburst that would effectively vary the yield[131]; the post-boost vehicle 'bus' could be programmed to deliver as manor as few of the loaded warhead re-entry vehicles (RVs) as might be required, with those not released burning up on re-entry (or potentially coming to earth without a nuclear yield but dispersing plutonium)[132]; and Trident missile warhead loadings could be reconfigured when the submarine is docked alongside before it goes out an operational patrol.[133]

Concerns about using Trident in a sub-strategic role were dismissed and on 18 October 1993 defence secretary Malcolm Rifkind announced in his statement on the 1993 Defence Estimates that Trident would take on the sub-strategic role given the high costs and technical risk of procuring a new stand-off nuclear weapon capability and the fundamental change in security circumstances with the end of the Cold War.[134] Therefore, when the WE177 was withdrawn from service in 1998 the sub-strategic role was wholly assigned to Trident with entry into service of the second boat, HMS Victorious.[135]

MoD intended to retain a national capability to design, develop and produce nuclear weapons in the future, including the capability to field a new warhead to meet a re-emergent requirement for a WE177.[136] A Draft Note in 1994 on the UK's nuclear warhead capability stated that there was no current basis for expecting such a requirement and therefore to retain the level of preparedness in warhead technology and the costs that would involve. After a period of two years, it would take an estimated three years to reinstate such a programme given run-down in expertise.[137]

---

[128] TNA DEFE 71/1286. Staff Target (Sea and Air) 1244: Air-Launched Theatre Nuclear Weapon. Two Star Draft. 7 April 1988.
[129] TNA DEFE 71/1286. ST(SA)1244 – Data Pack for France. Possibility of French Solution – Cardinal Point Specification. 16 March 1989.
[130] TNA DEFE 71/1303. RN Involvement in FTNW. 4 July 1991.
[131] TNA DEFE 25/812. UK Sub-Strategic Nuclear Capability. 25 October 1991.
[132] TNA DEFE 25/812. UK Sub-Strategic Nuclear Capability. 1 November 1991.
[133] TNA DEFE 25/812. UK Sub-Strategic Nuclear Capability. Draft letter from PS/S of S to PS NO 10 containing a paper on the Rationale For UK Sub-Strategic Capability. 22 October 1991; TNA AIR 8/3882. The Future Operating Posture of the Trident SSBN Deterrent Force. 16 June 1994.
[134] Statement On The Defence Estimates. Volume 230: debated on Monday 18 October 1993, Col. 34
[135] Secretary of State for Defence. Defence Estimates 1996, p. 24.
[136] Statement On The Defence Estimates. Volume 230: debated on Monday 18 October 1993, Col. 37.
[137] TNA AIR 8/3882. DRAFT NOTE FOR OPD(N). UK nuclear warhead capability and prospects for cooperation with France and the US. 1993 (no date).

Summary

The programme to procure a replacement for the WE177 therefore faced a number of challenges: first, the ever decreasing credibility of the Tornado/WE177 weapon system in the TNW role and the growing risk of a significant component failure across the WE177 stockpile that could require urgent withdrawal; and second, warhead design and production capacity limits at AWE and projected in-service dates of the potential delivery vehicles under consideration that all pushed an in-service date into the early 2000s at best and much later at worst.[138] The US decision to cancel the W91 and its non-nuclear components was a pivotal driver of the UK decision to cancel the FTNW programme.

One interviewee stated that most of the RAF including senior officers were glad to relinquish the nuclear mission. With the formal transfer of the strategic nuclear mission to the Royal Navy and the Polaris ballistic missile submarines in 1969, nuclear weapons had ceased to be the RAF's core mission. Later generations were pleased to lose the nuclear mission because it was distorting the role of the RAF post-Cold War due to the costs of a nuclear capability and its effect on organisation and aircraft procurement choices.[139] Even if some in the RAF would like to have kept a nuclear role to be seen to be supporting the national nuclear capability, a new standoff missile and warhead would have come out of the RAF budget at colossal cost.[140] Release of Tornado squadrons from the strike role into the general RAF conventional force was also a significant opportunity benefit for the air force.[141]

---

[138] TNA DEFE 71/1303. FTNW: Actions Placed at Follow-on DUS(P) Meeting. 24 September 1991; TNA DEFE 71/1286. MoD Equipment Policy Committee ST(SA)1244 Future Theatre Nuclear Weapon. Fourth Draft. 7 April 1988.
[139] Interview#4.
[140] Interview#11.
[141] Interview#9.

3. Re-nuclearising the RAF

This section explores what would be required to re-nuclearise the RAF based on this history, and, based on expert judgements about the time, cost and difficulty of doing so, to what extent we can conclude that the denuclearisation of the RAF in the 1990s was to all intent and purposes irreversible. This exercise in informed speculation is supported by the Conservative-Liberal Democrat Coalition government's 2013 Trident Alternatives Review (TAR) and responses to it. The TAR examined alternatives to the current SSBN system. One of the generic options was the design and development of a new warhead and its integration into a cruise missile or bomb for delivery by fighter aircraft - in essence a hypothetical 're-nuclearisation' of the RAF.

From the history outlined above, re-nuclearising the RAF would require:

1. A convincing rationale and concept of operations
2. RAF, Cabinet and Treasury support
3. US support
4. Integration into NATO/UK doctrine, targeting and command and control
5. A new nuclear warhead (unless supplied by the US)
6. A new delivery vehicle (unless supplied by the US)
7. Provision of and integration with strike aircraft
8. Air bases with secure weapon storage, HAS and hardened operations centres
9. A robust training and evaluation infrastructure
10. A robust support, security and safety infrastructure
11. Public support

A number of former policy-makers and practitioners involved in the WE177 programme, RAF and Ministry of Defence during the 1980s and 1990s were interviewed for this research, many of whom participated in a closed workshop in February 2024. Those involved at a senior level were clear that safely, securely and credibly deploying a nuclear weapon is a huge industry and that the challenges of doing so are often underestimated. Their view was that deploying nuclear weapons is very complicated, expensive and carries increments of risk that added together become cumulative and a very significant burden upon the armed service in question, MOD and the state.[142] Regenerating an air-delivered nuclear capability against any new requirement would be extremely expensive and very difficult.[143] The UK nuclear experience suggests that such a programme would inevitably encounter delays, shortages and engineering challenges such as those that hampered the UK weapons programme at various stages from its outset.[144]

The UK defence budget remains highly constrained. The RAF, MOD and Chief of the Defence Staff (CDS) would need to define the strategic case for a new nuclear weapon and senior leadership support would be required within MOD and the central machinery of

[142] Interview#3.
[143] Interview#10; Interview#3.
[144] John R. Walker, (2012). Potential Proliferation Pointers From The Past: Lessons From The British Nuclear Weapons Program, 1952–69. *The Nonproliferation Review*, 19: 1; Walker. *British Nuclear Weapons and the Test Ban*.

government, notably the Treasury.[145] The Treasury would require a Strategic Outline Case, then an Outline Business Case and finally a Full Business Case from MOD that outlined the necessity and risks of the procurement programme, capital and whole life costs and continuing viability. The business case would have to address five key dimensions (strategic, economic, commercial, financial and managerial) and would be built around costs, assumptions and risks attached to MOD's eight 'Defence Lines of Development' (DLODs) for the programme. These are training, equipment, people, infrastructure, doctrine, organisation, information and logistics and together they provide a detailed picture of progress across all aspects of the capability being procured and that need to be brought together to constitute an effective military capability.[146]

Key questions facing a hypothetical new programme would include: What would be the deterrent requirement? How many planes? What range would be needed? How many missiles/warheads? What operating environments would a warhead be expected to encounter? How many bases would be required? What would the security requirements be for force protection? How would command and control procedures be added to existing national war plans as well as NATO planning? What would be opportunity costs for other options and conventional capabilities?

The major obstacles to redeveloping an air-delivered nuclear capability would therefore be those that generate significant costs, chiefly the warhead, missile and additional aircraft. The latter is significant because the frontline of the air force is much smaller today than it was 30 years ago, the defence budget is smaller and the armed forces as a whole are smaller. On that basis, it is difficult to see how the affordability of a new nuclear weapon and everything that goes with it could be squared.[147] However, putting a UK DCA force in place with US weapons could be possible given the infrastructure already in place.[148] There is also the historical precedent from the late 1950s and early 1960s with 'Project E' in which US nuclear weapons would have been made available for RAF use in wartime. However, there are costs and issues surrounding avionics, custody and authorisation to use such weapons.

There would also need to be sufficient latent public support (social licence) for developing a new nuclear weapon, deploying nuclear weapons to UK and potentially overseas airbases and justifying the cost.[149] The political acceptability of the cost in the UK could therefore be difficult unless there was a very clear and obvious threat-based justification.[150] Moreover, during the Cold War there was very little public awareness that the UK even possessed a tactical nuclear weapons programme – all the public focus was on strategic weapon systems and virtually nothing was written about the WE177 as even the designation of the weapon system was a well-guarded secret for much of the Cold

---

145 Interview#1.
146 Trevor Taylor (2020). The UK Ministry of Defence's Adoption of the Government-Wide System for Project Approvals. *Royal United Services Institute*. Commentary, 10 July. <https://rusi.org/explore-our-research/publications/commentary/uk-ministry-defences-adoption-government-wide-system-project-approvals>.
147 Interview#3.
148 Interview#12.
149 Interview#1.
150 Interview#4.

War. A decision to acquire a new theatre nuclear weapon would be very much in the public domain and might struggle for social acceptance.

Weapon system

Stand-off supersonic cruise missile

A new nuclear weapons system for the RAF would likely be based on one of three options:

1. A new warhead for a stand-off supersonic cruise missile based on the FTNW design.
2. A nuclear-sharing arrangement to deploy the US B61-12 precision-guided gravity bombs on UK DCA.
3. The Trident Holbrook warhead adapted for free-fall delivery.

The TAR examined a UK ballistic missile warhead, cruise missile warhead and free-fall bomb. The Review's starting point was that development of a new warhead would be the biggest challenge because the UK nuclear warhead programme is highly optimised around producing and maintaining Holbrook warheads for Trident. It would be challenging in terms of technical, financial and schedule risk for AWE to design and manufacture a new type of warhead whilst maintaining the Holbrook stockpile through a challenging warhead surveillance programme.[151] The timescale would also be considerable, with the TAR concluding that it would take around 24 years from initiation to full scale production, even if building upon a previous design, which the review assumed: "AWE facilities, techniques and expertise would need to be adapted; new non-nuclear components, different from those we procure today from the US would need to be developed (in the current absence of a similar US programme, this is assumed to be mostly on our own); and developing the delivery vehicle in parallel risks extending the programme, in contrast with Trident, for which the missile and its environmental data is well-known".[152]

In contrast it would take around 17 years to design, develop, certify and produce a ballistic missile-based thermonuclear warhead. The shorter time frame is because ballistic missile thermonuclear warheads are a relatively well-understood concept in the UK nuclear weapons complex, the UK has a long history of collaboration with the US on non-nuclear components for such a warhead, together with computer-based modelling codes and capabilities and extensive hydrodynamic trials in the absence of explosive nuclear testing. The cost of developing a new warhead for a cruise missile or free-fall bomb would also be significant, estimated in the TAR at £8-10Bn, compared to £4Bn for a new Trident warhead - all at 50% confidence.

The TAR judged that the timescales for develop a new warhead could be reduced by around 5 years if the programme were a national imperative, with associated cost implications, by "limiting the design work and accepting a short initial service life; designing the missile around the warhead; and delivering UK non-nuclear components as

[151] Cabinet Office (2013). Trident Alternatives Review, p. 18.
[152] Cabinet Office. Trident Alternatives Review, p. 6.

early as possible".[153] This was a key issue for workshop participants, who argued that although modern safety and security requirements for warhead design, production and operation are far more stringent today than in the 1960s when the WE177 was developed, these could be suspended if redevelopment of air-delivered capability were framed and accepted as a national emergency with a higher tolerance of risk and cost. In fact, a number of participants argued that if this became a core requirement and was funded accordingly, the UK would be able to do it with sustained top-down support from ministers and the Treasury. Industry would come on board if there were firm political decisions and accompanying expenditure and order. However, such a programme would still be very challenging and take a considerable period of time to deliver in the order of at least 15 years and therefore three governments.

The free fall bomb option was based on the WE177 but incorporating modern safety features. The warhead for the cruise missile option was based on work done for the FTNW and subsequent design work at AWE as part of a 'challenge programmes' to maintain proficiency, train the next generation of warhead designers, exercise the advanced warhead design and diagnostic tools at AWE, and address endemic workforce problems.[154] Adapting the Holbrook warhead for FTNW was considered and dismissed in the late 1980s.[155]

A number of delivery systems for a fast jet were explored including a subsonic cruise missile, supersonic cruise missile and free fall bomb. The TAR judged that developing and manufacturing a free fall bomb would not pose a significant technical challenge for UK industry, but integrating the warhead with the aircraft to meet the necessary nuclear assurance requirements would be more challenging. Production of a stealthy subsonic cruise missile would draw heavily upon current UK conventional cruise missile technologies, such as Storm Shadow. Developing a supersonic cruise missile would be more challenging and come with more risk and uncertainty since UK industry has less experience of designing and manufacturing high speed missiles. Technology transfer from allies could reduce the risks if countries were willing to collaborate.[156] However, only the supersonic cruise missile was taken forward in the TAR's final analysis for the fast jet option based on range, vulnerability and ability to penetrate defensive systems.[157] This mirrored the conclusion of the Theatre Nuclear Weapons Policy Steering Group (TNWPSG) in 1986. In practice, the sophistication, range, and stealth requirements for a nuclear cruise missile would depend on the types and locations of targets the new missile capability was intended to destroy.

---

[153] Cabinet Office. Trident Alternatives Review, p. 37.
[154] Ellen Williams, et al. (2012). *The Comprehensive Nuclear Test Ban Treaty: Technical Issues for the United States*. US National Academy of Science, Washington, D.C., p. 84. The warhead design was reportedly for a cruise missile. Private correspondence from a participant in a meeting in Washington, D.C., with an AWE Aldermaston official in November 2009.
[155] Wyn Bowen and Geoffrey Chapman argue using Trident warheads for air-dropped gravity bomb delivery "would require a modified arming and fusing mechanism, but could potentially use existing aircraft, such as F-35s, as a delivery platform. This option was floated by a defence official in the 1990s as an ersatz replacement capability if Trident missiles became inoperable, but still came with the warning that costs would be 'very substantial'". Wyn Bowen and Geoffrey Chapman (2022). The UK, Nuclear Deterrence and a Changing World. Freeman Air and Space Institute, King's College London, p. 12.
[156] Cabinet Office. Trident Alternatives Review, p. 36.
[157] Cabinet Office. Trident Alternatives Review, p. 18.

Integration of a new warhead with the delivery vehicle to create an integrated nuclear-capable system would be the main risk and cost factor. The TAR noted that "The UK has no recent experience of designing an integrated nuclear warhead and missile capability on its own; it would be essential to establish a UK nuclear systems integration organisation in order tightly to manage the collaboration between AWE and the missile industry".[158]

US B61-12 and UK DCA

A 2015 Centre Forum report by Toby Fenwick detailed an F-35C Joint Strike Fighter (JSF) alternative to Trident using the US B61-12 precision-guided free fall bomb. The TAR did not consider a nuclear-sharing arrangement to use the US B61-12 because its options were based on production of a UK warhead. The B61-12 will provide the free-fall bomb for NATO Dual-Capable Aircraft and is currently being integrated onto the F-35A JSF. This would, according to Fenwick, significantly reduce the costs and complexity of developing, manufacturing and integrating a new supersonic cruise missile.[159] As Bowen and Chapman note, B61-12 nuclear sharing "would not be unprecedented – the UK operated US Thor missiles, as well as fielded US loaned tactical nuclear artillery and the Lance missile system during the Cold War. The UK already hosts US nuclear-capable aircraft at RAF Lakenheath, with nuclear storage bunkers there currently being renovated".[160]

Allied support

The challenges of developing a new warhead would be eased through acquisition of key non-nuclear components from the US in line with current practice, though this would depend upon US willingness to do so and a comparable US programme with which to align.[161] Workshop participants noted that support from the US would be critical to developing a FTNW-equivalent with today's technologies. Support would be managed through the 1958 MDA's JOWOGs, though it could not be assured.[162] US support would also be essential for certifying the F-35B or F-35C to carry a new nuclear weapon, or for a new nuclear-sharing arrangement using US B61-12s on a UK F-35C fleet. Re-nuclearising the RAF would be simpler if the UK could procure a US nuclear-armed missile with a warhead design and non-nuclear components that could be shared with the UK.[163]

A key consideration would be whether the US would be willing or grudging in its support for the development and acquisition of an RAF nuclear capability. The UK would need to draw on US data to help certify the safety of non-nuclear components. It is very expensive to generate such data and the UK no longer makes such components and it would likely take decades to restore this capability.

[158] Cabinet Office. Trident Alternatives Review, p. 36.
[159] Toby Fenwick (2015). Retiring Trident: An Alternative Proposal for UK Nuclear Deterrence. *Centre Forum*, London, pp. 34-36.
[160] Bowen and Chapman. The UK, Nuclear Deterrence, p. 12.
[161] Cabinet Office. Trident Alternatives Review, p. 44.
[162] Graham Spinardi, (1997). Aldermaston and British Nuclear Weapons Development: Testing the 'Zuckerman Thesis'. *Social Studies of Science*, 27:4, pp. 547-582.
[163] Interview#1.

Wyn Bowen and Geoffrey Chapman suggest the UK could develop a new nuclear-capable cruise missile, potentially in collaboration with France, the new ASN4G (Air-Sol Nucléaire de 4ème Génération) hypersonic cruise missiles in development to replace its ASMP missile (Air-Sol Moyenne Portée - medium-range air to surface missile).[164] However, the FTNW experience suggests collaboration with France on a missile and integration of a UK warhead would be problematic.

AWE capacity

It is likely that the capacity to design, certify and manufacture a new nuclear warhead at AWE would be limited and that increasing its capacity would be very expensive.[165] One interviewee noted that it is challenging to maintain one warhead type at AWE with current diagnostic capabilities, two would be even more challenging.[166] This is in part because the design of a warhead for a supersonic missile would likely require different primary and secondary designs to the Trident Holbrook warhead, around which the entire UK nuclear enterprise is optimised.[167] It was noted that the Nuclear Weapons Capability Sustainment Programme (NWCSP) initiated in 2005 to develop major new diagnostic, testing and manufacturing capabilities at AWE Aldermaston and Burghfield has 'locked in' a set of capabilities and practices based on sustained the Holbrook warhead and producing a replacement that will be very similar to it. Moreover, the design space for developing a new warhead is very conservative because the inability to conduct new explosive nuclear tests following ratification of the 1996 Comprehensive Test Ban Treaty (CTBT) limits the range of warhead designs that could be certified as safe and reliable.

There would probably need to be a recruitment drive for physicists, chemists, nuclear engineers and technicians and programme managers at AWE, but how many would depend on what needed to be done with the Trident system at the time.[168] This could be a challenge given AWE's ongoing problems with recruitment and retention.[169] The UK would also need sufficient quantities of special materials for warhead production, particularly Tritium.[170] One interviewee noted that AWE regretted cancellation of FTNW and all that went with it because one significant consequence of having a single weapon is long periods when skills are not being developed on new projects. A number of interviewees were of the view that AWE would find it very difficult if not impossible to contemplate another warhead.[171] A lot of this echoes the warnings from Vic Macklen – a senior MOD official responsible for nuclear policy – in the 1960s and 1970s on what was needed to maintain a minimum capability at Aldermaston and to retain expertise in the event that Ministers decided that the UK needed to develop a new generation of strategic and tactical nuclear weapons.[172]

---

[164] Bowen and Chapman. The UK, Nuclear Deterrence, p. 12.
[165] Interview#1.
[166] Interview#10.
[167] Interview#5.
[168] Interview#5.
[169] Interview#3.
[170] Interview#10.
[171] Interview#12.
[172] See for example, Walker, *British Nuclear Weapons and the Test Ban*, pp. 40-41.

Aircraft

F-35 choices

The TAR used the F-35 Joint Strike Fighter to model its fast jet option and assumed the fast jet fleet would be dual-capable. Such a fleet would need to be deployed and ready to conduct (or be conducting) conventional strike operations at the same time as maintaining enough platforms and crews at readiness to deliver a nuclear strike. Flight trials would be needed to ensure integration of a new stand-off missile with the airframe was satisfactory for aircraft, missile and warhead design authorities and their safety cases. An F-35 option would require this process to be done in the US. Accrediting the aircraft and airbases to deploy the missile and warhead after trials is an intensely complex and lengthy process.[173] The standoff system would have to be extensively trialled and tested under high stress conditions for nuclear release to ensure detonation using testing equipment that would be needed to reproduce exactly how the aircraft would operate.[174]

Fenwick's proposal envisaged a dual-capable F-35 fleet with aircrew trained for the nuclear mission as part of their normal training in line with NATO DCA training and following the experience of Tornado squadrons equipped with the WE177.[175] However, the current air force is small by historical standards and reinstating a nuclear mission would likely require more aircraft, though this would depend on the level of operational readiness for the strike mission, notably whether a QRA posture was required. For example, the size of the RAF in 2023 was 31,000 and in 1990 at the end of the Cold War it was 90,000.

However, the B61-12 cannot be carried internally on the F-35B procured by the UK due to its smaller bomb bay and deploying the weapon externally would undermine the aircraft's stealth capabilities making it more vulnerable to interception. It is therefore unlikely the F-35B will be nuclear-certified.[176] The UK initially opted to procure the F-35B short take-off and vertical landing (STOVL) variant for deployment on its new Queen Elizabeth-class aircraft carriers, recommended by the Royal Navy in 2002 and approved in 2006. In 2010 the new Coalition government changed course and announced that the UK would instead purchase the F35C variant and equip the carriers with a Catapult Assisted Take-Off and Barrier Arrested Recovery (CATOBAR) 'cat and trap' system to launch and land the aircraft. However, the carriers were not designed for a 'cat and trap' system and would need to be modified at an estimated cost of £5 billion.[177] In the end, the UK proceeded with the F-35B and has at the time of writing purchased 74 out of a total planned purchase of 138. Participating in NATO nuclear sharing using the B61-12 would therefore require the UK to substitute some or all future F-35B purchases for the F-35C, which can accommodate the B61-12 in its bomb bays, retrofit one or both carriers with a 'cat and trap' system if the F-35Cs were to be deployed at sea, and train pilots and flight deck crew in the more demanding task of arrested landings on a carrier deck.

---

[173] Interview#3.
[174] Interview#7.
[175] Fenwick. Retiring Trident, p. 40.
[176] Fenwick. Retiring Trident, p. 39.
[177] Nick Hopkins (2021). Philip Hammond defends aircraft carrier U-turn. *The Guardian,* 10 May.

This demonstrates how existing delivery vehicles can limit re-nuclearisation pathways. In Germany, for example, Berlin's intention in the late 2010s was to replace its ageing Tornado DCA with the Eurofighter Typhoon with the F-35, F-18 and F15 as secondary options.[178] Neither Typhoon nor the Super Hornet is certified to carry US nuclear weapons and in 2018 German officials asked the US about certifying Typhoon to carry US B61 nuclear weapons. This would require wiring systems for nuclear weapons and nuclear release to be totally separated from all other electronics in the aircraft.[179] Reuters reported that the F-35 and other aircraft had to be certified first and that it could take 7-10 years to certify the Eurofighter for nuclear missions, well beyond the Tornado's retirement date.[180] Certifying the F-18 would take about half that time.[181] Eventually in 2022, Germany opted to buy 35 nuclear-certified F-35As to take on the Tornado DCA nuclear mission.[182] This reinforces the requirement that nuclear wiring needs to be designed into a dual-capable aircraft followed by a long certification process to clear the aircraft for the safe carriage of nuclear weapons. In the RAF during its nuclear days, this task was performed by Controller Air, a senior three star appointment within the Air Staff and his branch. The F-35A was finally certified to carry the B61-11 bomb in March 2024 after a 10-year nuclear certification programme. The certification only applies to the F-35A, not the B and C variants.[183]

Fleet size and pilot training

If redeployment of nuclear weapons required additional aircraft, then this would require a larger aircrew and larger throughput of pilot and aircrew training systems. Interviewees noted that this would depend on capacity, time and cost and assumes that enough people could be recruited and retained for these roles.[184] Given the current small size of the air force, adding a nuclear role would require an increase in aircraft and crews and this would not be straightforward.[185] More people, hardware, technical understanding, training, and security processes would be very expensive.[186] Additional aircraft could be needed not just for nuclear delivery but also escort aircraft to maximise in-flight survivability.[187] Re-nuclearising the RAF would require RAF Valley, where the UK's fast jet pilots are trained, to expand its courses, instructors, simulators and numbers of aircraft to support such an expansion, which would be challenging.

In 2023 the House of Commons Defence Committee was highly critical of the state of the RAF's pilot training programme and the size of the UK's fast jet fleet, describing it as "a

---

[178] Sabine Siebold (2017). Germany favours Eurofighter as it seeks to replace Tornado. *Reuters*, 11 December <https://www.reuters.com/article/us-germany-defence/germany-favors-eurofighter-as-it-seeks-to-replace-tornado-idUSKBN1E52EK/>.
[179] Interview#3.
[180] Andrea Shalal (2018). Germany presses U.S. on potential Eurofighter nuclear role. *Reuters*, 20 June <https://www.reuters.com/article/idUSKBN1JG1K0/>.
[181] Sebastian Sprenger (2019). Boeing's F-18 jet may have a leg up in Germany over Eurofighter. *Defense News*, 4 October <https://www.defensenews.com/global/europe/2019/10/04/boeings-f-18-may-have-a-leg-up-in-germany-over-eurofighter/>.
[182] Sprenger. Germany to buy F-35 warplanes.
[183] Michael Marrow (2024). Exclusive: F-35A officially certified to carry nuclear bomb. *Breaking Defense*. 8 March. <https://breakingdefense.com/2024/03/exclusive-f-35a-officially-certified-to-carry-nuclear-bomb/>.
[184] Interview#12.
[185] Interview#3.
[186] Interview#3.
[187] Cabinet Office. Trident Alternatives Review, p. 47.

boutique high capability". It said there were "serious questions as to whether the UK's diminished combat air fleet can successfully deter and defend against enemy aggression. Whilst made up of highly capable aircraft, it is just too small to withstand the levels of attrition that would occur in a peer-on-peer war. The imminent retirement of the Tranche 1 Typhoon and continued slow force growth of the F-35 fleet will only exacerbate these shortcomings: the MoD and RAF must urgently address this lack of combat mass".[188]

The report noted that the growth rate of the UK's F-35 fleet had been slower than planned because of problems recruiting aircraft mechanics[189] and "persistent and unacceptable delays in the flying training pipeline mean that pilots are waiting years to qualify, with serious implications for morale and for the effectiveness of our armed forces".[190] Problems with the UK's Military Flying Training System (MFTS) that was outsourced in 2008 to Ascent Flight Training (Management) Limited, a joint venture between Lockheed Martin UK and Babcock International, were the subject of National Audit Office (NAO) investigations in 2015 and 2019. These highlighted a shortage of qualified instructors and poor aircraft availability. In 2019 "145 RAF students were due to start their Phase 2 training, having waited an estimated average of 90 weeks, compared with an expected position of 26 students waiting 12 weeks; As at 31 March 2019, 44 out of the 369 planned MFTS courses had been cancelled due to one or other party failing to fulfil its responsibilities".[191] One interviewee noted that it should take three years back to back to train a fast jet pilot but the process is currently so constrained with lots of holding between elements of training that it is taking up to 7 years.[192]

Training aircrew and ground crew for transporting, loading and maintaining nuclear weapons and nuclear release was not judged to be problematic since aircrews adapt very quickly to carrying new weapons systems, such as Storm Shadow or Brimstone.[193] However, pilots would have to go through a different psychological selection process for the nuclear mission.[194] In addition, recruitment, development of training manuals and SOPs would still take time before a sufficient establishment of qualified personnel could be declared operational.

Supporting infrastructure

Air bases

The TAR assessed that a fast jet option would require "investment in new or refurbished nuclear infrastructure at their main operating bases, including highly secure and environmentally-controlled facilities for the handling, integration and maintenance of the warheads and missiles behind multiple layers of security. The cost estimates include the

188 House of Commons Defence Committee (2013). Aviation Procurement: Winging it? HC 178. HMSO. London, p.10.
189 House of Commons Defence Committee. Aviation Procurement, p. 11.
190 House of Commons Defence Committee. Aviation Procurement, p. 29.
191 House of Commons Defence Committee. Aviation Procurement, p. 30.
192 Interview#3.
193 Interview#3.
194 Interview#11.

construction and maintenance of these facilities to nuclear regulatory standards of safety, security and radiation hardness".[195]

There would need to be additional facilities constructed at RAF bases but it's possible that the basic design principles for those could draw on previous UK practices and those currently used at NATO allies that operate DCA or US bases.[196] New Supplementary Storage Areas for secure storage of nuclear weapons or weapon storage vaults in HAS would need to be constructed at a number of bases to store new nuclear cruise missiles or B61-12 bombs. Kristensen reports that the 24 WS3 vaults at RAF Marham were dismantled following their deactivation in 1998. The 33 WS3 vaults installed at RAF Lakenheath in the 1990s that can hold up to four B61 bombs each were only mothballed and could be reactivated with US support.[197] Hardened aircraft shelters could need modernising. Overall, an increase in RAF squadrons would tax the whole fast jet infrastructure currently in place.

A QRA posture would require more personnel and probably more aircraft, or sacrificing existing roles. During the Cold War, QRA bases required an additional 190 people to staff and guard, comprising engineering, fire and police personnel, air traffic control, operations, and 8 vehicles.[198] Retention of a substantial number of support posts would be necessary for maintaining a QRA posture.[199]

Safety and security

Safety, security and inspection processes would need to be redeveloped. However, interviewees stated that reintroducing training courses and the Taceval process would not be too difficult.[200] An examination and training system, associated manuals for air and ground crews and an armament support unit would need to be set up again to run Tacevals and other exercises, which would be limited by the size of the training team, which would have to be developed.[201] Stations would need their own training staff to train their crews for the standardisation inspection and evaluation process.[202] Documentation would include training manuals; individual personnel security manuals for appropriate clearance; technical manuals for a new weapon system; performance manuals for the aircraft with weapon deployed; training manuals, and simulators.[203]

---

[195] Cabinet Office. Trident Alternatives Review, p. 39.
[196] Interview#5.
[197] Hans Kristensen (2005). 'U.S. Nuclear Weapons in Europe A Review of Post-Cold War Policy, Force Levels, and War Planning'. Natural Resources Defense Council, Washington, D.C. <https://www.nukestrat.com/pubs/EuroBombs.pdf>. There is evidence to suggest that this process is in fact underway to allow redeployment of UK B61 bombs that were withdrawn in 2007 for delivery by US F-15E DCA stationed at the base. US F-15Es remain at the base together with 24 nuclear certified US F-35As. Hans Kristensen (2022). 'Lakenheath Air Base Added To Nuclear Weapons Storage Site Upgrades'. Federation of American Scientists. 11 April <https://fas.org/publication/lakenheath-air-base-added-to-nuclear-weapons-storage-site-upgrades/>.
[198] TNA AIR 8/2681. Study of the Practical Aspects of Removal or Reduction of QRA Requirement in RAF Germany. February 1976.
[199] TNA AIR 8/2681. Study of the Practical Aspects of Removal or Reduction of QRA Requirement in RAF Germany. February 1976.
[200] Interview#2.
[201] Interview#6.
[202] Interview#6.
[203] Interview#7.

The current nuclear safety regime for Trident warheads could also overlap onto whatever the RAF wanted to put in place.[204] RAF police units would need to be expanded and trained to guard aircraft and weapon systems.[205] Fire rescue training and special safety teams would be needed to deal with nuclear accidents at airbases.[206] The RAF would also draw on the Navy's special safety processes, convoy escort and standardisation.[207] For example, weapon movements between RAF bases and AWE for deployment and maintenance would require specialist vehicles, organisation and safety and security personnel for the road movements. These would be the same as those for Trident.[208]

Doctrine and organisation

The RAF would need to generate doctrine and training drawing on relevant current RN practices, previous practices with WE177, and current NATO DCA practices. There are concerns in MoD about current levels of nuclear expertise. As time moves on, tacit knowledge of RAF nuclear operations diminishes, and this could make re-nuclearising the RAF very difficult.[209] The scale of the task would depend in part on what could be retrieved from past experience and records, and this might be limited. However, current RN, police, and NII nuclear warhead safety and security processes would not be very different if a new air-delivered weapon were introduced.[210]

Re-nuclearising the RAF would also change the service. After the Cold War the RAF got ever smaller through successive defence reviews, as RAF developed a new role in the post-Cold War era. The RAF's defining role post-1945 was the strategic and then tactical nuclear weapons mission. That strategic bombing tradition is now history and with it the Cold War nuclear infrastructure, knowledge, culture and organisation.[211] After the Cold War and Gulf War, the RAF's role shifted to air transport, helicopters, mobility, and conventional attack with a new generation of smart weapons and now UAVs.[212] Some interviewees were of the view that re-establishing a nuclear culture for the management of nuclear weapons inside the RAF would be difficult and would take time to build up.[213] A change in culture experienced by the RAF makes it more difficult to reverse, especially since the current cadre of middle and senior officers did not come through the ranks performing nuclear roles.[214] Others argued that the reintroduction of a nuclear mission would not be difficult for the RAF. It would quickly adapt and regenerate the necessary doctrine, culture and practices for nuclear tasking, targeting, and maintaining the integrity of the firing chain.[215] The RAF would no doubt seek assurances that a new nuclear mission would not come at the expense of other valued assets, but this could be very difficult to ensure.[216]

---

[204] Interview#9.
[205] Interview#6.
[206] Interview#6.
[207] Interview#6.
[208] TNA AIR 8/3882. WE177 – Weapon Storage Vaults. Annex A: UK Sub-Strategic Capability - Early Withdrawal of WE177. Letter from David Omand DUS(P) to CDS, PUS and CDP. 9 May 1994.
[209] Interview#1.
[210] Interview#2.
[211] Interview#1.
[212] Interview#1.
[213] Interview#4.
[214] Interview#7.
[215] Interview#3.
[216] Interview#1.

Nuclear command and control for UK DCA would need to be redeveloped. The TAR reports that an alternative nuclear system would require nuclear command, control and communications coverage “of very different operating areas than at present. Developing an assured global sovereign capability would require very significant investment” even based on re-use and extension of existing systems.[217] Assured command and control might also require new or refurbished hardened Operations Centre at air bases hosting strike aircraft.[218] Decisions on utilisation and integration with other activities would be done in permanent Joint HQ Northwood. Secure encrypted communications for nuclear release authorisation would be needed between Northwood, RAF Air Command at High Wycombe and RAF airbases. However, interviewees noted that targeting of conventional weapons is already very tightly controlled and a nuclear targeting process could be overlaid on this.[219] Dispersal airfields might also need to be part of the planning process as it was in the days of the V-Bombers; however, with far fewer operational airbases this could be quite a challenge.

Air-to-air refuelling and airborne early warning

Targeting would depend on the range of the aircraft and missile system and availability of air-to-air refuelling. Fenwick’s proposal included conversion of the RAF’s Voyager KC2 / KC3 fleet to provide “flying boom” refuelling with the Airbus Air Refuelling Boom System (ARBS) and to receive fuel themselves with a Universal Air Refuelling Receptacle System Installation (UARRSI) receiver.[220] This could require an expansion of the UK tanker fleet. One interview noted that one of the reasons why France can be inflexible in providing additional air-to-air refuelling assets is because they have assigned a number of their tankers to support their nuclear capability. Re-nuclearisation of the RAF would therefore have a knock on effect on the tanker fleet and maybe on a wider set of ISR assets.[221]

Fenwick’s proposal also required airborne early warning (AEW) from RAF’s E-3D Sentry AWACS and/or the FAA E-2D AWE&C, real-time electronic surveillance from RC-135W RIVET JOINT aircraft via high-fidelity datalinks, and fighter escort.[222] However, the House of Commons report cited above also highlighted challenges with the UK’s Airborne Early Warning & Control capability following the retirement of the E-3D Sentry fleet in 2021. This left the UK without a land-based fixed-wing Airborne Early Warning & Control capability until the Sentry’s replacement, the E-7A Wedgetail, is brought into service with three aircraft rather than the five originally ordered due to MoD cost savings.[223]

[217] Cabinet Office. Trident Alternatives Review, p. 39.
[218] Royal Air Force Historical Society (2002). The Birth of Tornado. *Royal Air Force Historical Society Journal* 47, p. 108.
[219] Interview#7.
[220] Fenwick. Retiring Trident, p. 52.
[221] Interview#12.
[222] Fenwick. Retiring Trident, p. 57.
[223] House of Commons Defence Committee. Aviation Procurement, pp. 19-20.

Conclusion

The broad range of activities, equipment and infrastructure of the sort discussed here are required to turn the weapons grade fissile material arising from a fuel cycle into a fully engineered weapons system embedded into a state's military posture and practice. This does not happen spontaneously and neither is it self-sustaining if credibility, reliability, readiness, safety, and security are all to be maintained in equal measure. Conversely, the absence of such activities, equipment and infrastructure means that as the years advance since the decision was taken to denuclearise the RAF, the time, effort and cost of restoring them to even minimum operational levels would be considerable and by no means trivial.

Nevertheless, re-nuclearising the RAF would not be impossible: there is no fundamental technological reason why the UK could not do this and with enough time, money and commitment, the RAF could deploy a nuclear-armed standoff cruise missile or the US B61-12 bomb. Re-nuclearisation of an armed service would, much like the potential re-nuclearisation of a disarmed state, draw on the 'institutional remnants' of a nuclear programme and extant capabilities and capacities. In our hypothetical case of re-nuclearising the RAF, there are 'institutional remnants' of the FTNW programme to draw on, specifically: work done on the FTNW warhead design, interface and missile selection and additional design work through AWE 'challenge' programmes; and tacit and explicit knowledge of Tornado-WE177 systems and operations that could be recovered or reconstituted.

In addition, the UK's extant nuclear weapons complex and combat aircraft and missile production infrastructure provide a foundation of: nuclear warhead design, testing and production capabilities at AWE Aldermaston and Burghfield; Royal Navy nuclear weapon security, training, evaluation, transport and support expertise, knowledge, operations and infrastructure; Navy, MOD and Cabinet Office nuclear weapons doctrine, organisation and command and control policies, systems and processes; the social licence for continuing to deploy nuclear weapons evidenced in public opinion polling;[224] a 5th generation multi-role combat aircraft fleet and training and support infrastructure based on the F-35 and work underway with European allies on a next-generation Tempest combat aircraft to replace the Eurofighter Typhoon from 2035; and a stealthy cruise missile design, production and support infrastructure.

Yet even with this foundation, detailed understanding of the original UK WE177 'ecosystem', which itself took from 1959 until 1977 to be fully realised, analysis of the aborted FTNW programme, and interviews with former policy-makers and practitioners involved in the nuclear RAF and nuclear policy during the FTNW process, suggests that re-nuclearising the RAF and re-constituting an RAF nuclear ecosystem would be extremely challenging. It would mean putting back together the ecosystem's materials (technologies and infrastructure), meanings (that make sense of air-delivered nuclear weapons),

[224] John Curtice and Alex Scholes (2023). Role and responsibilities of government Have public expectations changed? British Social Attitudes 40. *National Centre for Social Research*, September. Table 5, p. 27 <https://natcen.ac.uk/sites/default/files/2023-09/BSA%2040%20Role%20and%20responsibilities%20of%20government.pdf> .

competencies (expertise across multiple domains) and institutions (for safe and secure governance of air-delivered nuclear weapons). The UK took many years to grow the 'system of systems' sufficient to support an air-delivered capability. This continued into the 1990s but was then not replaced as the cost and difficulty of the FTNW programme increased, political and strategic conditions made it a safe option to atrophy the capability, and Trident could be framed as a flexible system capable of delivering a 'sub-strategic' strike.

Moreover, such a programme would undoubtedly face delays, problems and shortages that have impeded the UK nuclear programme since its inception. This includes the availability of skilled and experienced personnel and engineers, production capacity and availability of key materials and weapon components, challenges of testing and certifying components and compatibility with delivery vehicles and modes of delivery, competing pressures on other defence and national scientific programmes and priorities, and the challenges of retaining resources and expertise to sustain a nuclear weapon system in service.[225]

This case study suggests that the key to irreversibility is the difficulty of the political, military and economic case for reversing a denuclearisation process given the foreseeable time, cost and complexities involved and the opportunity costs. This highlights the relationship between technology and meanings: technologically, the primary challenge would be production and integration of a new warhead and missile with a strike aircraft unless a US B61-12 solution were sought. Then there would be costs of procuring additional aircraft, particularly if a QRA posture were considered essential, and potentially fitting a 'cat and trap' system to one or both Queen Elizabeth Class aircraft carriers.

This is not technologically or financially impossible, but it would require a shared understanding of the absolute necessity of re-nuclearisation in order to generate a sustained political and financial commitment given the cost, timescale and complexity of the task and the risks involved. I.e., there would need to be a shared system of meaning across the RAF, MOD, Prime Minister and Treasury that made sense of the procurement of an air-delivered UK sub-strategic nuclear capability as a *necessary* response to a clear, obvious and long-term threat. The risks of cost escalation, delay, and technological challenges and opportunity costs of allocating limited defence resources and expertise and capacity to such a system would have to be accepted and resistances overcome.

At the same time, it is likely that even if the idea of procuring an air-delivered UK sub-strategic nuclear capability gained momentum as a plausible response to an enduring threat, a crucial prerequisite for endorsement would be confidence in appropriate design and production systems, processes, tools, materials and facilities, engineering and project management capacity and expertise (suitably qualified and experienced personnel) to develop and deploy a complex new nuclear weapon acquisition programme within an acceptable timescale and at an acceptable cost.[226] As with other major procurement

[225] Walker. Potential Proliferation Pointers from the Past.
[226] Lucia Retter, Julia Muravska, Ben Williams, and James Black (2021). *Persistent Challenges in UK Defence Equipment Acquisition*. Santa Monica, CA: RAND Corporation <https://www.rand.org/pubs/research_reports/RRA1174-1.html>.

projects, the estimated time, cost and difficulty of reconstituting, reinventing and expanding necessary capabilities and capacities would shape the seriousness with which re-nuclearisation would be considered given the perceived interests at stake. This is further challenged by MoD's history of 'optimism bias' and long and expensive cost-overruns with major procurement programmes, including within the UK military nuclear complex.[227]

In addition, it highlights the role of the wider structure of rules, laws, standards and SOPs that would shape the procurement of an air-delivered nuclear weapon system.[228] There are bureaucratic processes to be navigated and coordinated by multiple stakeholders to get the procurement of a major new weapon system underway. There are established and overlapping health, safety, security, planning, training, budgeting, contracting, production, testing, evaluation regimes in place that generate complexity, obstacles, expense and delay.[229] And there are

Beyond the primary challenges of political support and material production of the weapon system lies a secondary set of challenges centred on essential support infrastructure without which there is no operational capability, which is the primary purpose of nuclear weapons possession. Scholarship on large socio-technical systems shows that "Artefacts do not 'work' unless they are placed in a wider configuration that works".[230] These may be more surmountable than the challenges of generating material components, but would nonetheless be costly and challenging and require expanding and re-establishing core competencies in nuclear command and control, airbase facilities and operations, training and evaluation, weapon security, and weapon safety and surveillance. It is the absence of these sorts of attributes that would help maintain a status of nuclear irreversibility.

---

[227] See Bernard Gray (2009). Review of Acquisition for the Secretary of State for Defence. <https://webarchive.nationalarchives.gov.uk/ukgwa/20120913104443/http://www.mod.uk:80/DefenceInternet/AboutDefence/CorporatePublications/PolicyStrategyandPlanning/ReviewOfAcquisition.htm> and House of Commons Committee of Public Accounts (2020). Defence Nuclear Infrastructure. Second Report of Session 2019–21. HC 86. HMSO, London.

[228] For a framework, see Hans Klein and Daniel Kleinman (2002). The Social Construction of Technology: Structural Considerations. *Science, Technology, & Human Values* 27: 1, p. 35.

[229] This is especially so for the development of a new capability. See Fred Bennett (2010). The Seven Deadly Risks of Defence Project. *Security Challenges*, 6: 3, pp, 97–111 and House of Commons Defence Committee (2023). It is broke — and it's time to fix it The UK's defence procurement system Ninth Report of Session 2022–23. HC 1099. HMSO, London.

[230] Frank Geels (2005). *Technological Transitions and System Innovations.* Edward Elgar, Cheltenham, p. 51.

PROJECT ON IRREVERSIBLE NUCLEAR DISARMAMENT

Working papers

Joelien Pretorius. **Staying the course: Lessons from South Africa for irreversibility of nuclear disarmament**. March 2023. York IND Working Paper#1.

Nick Ritchie. **Conditional Reversibility as a Condition of Irreversibility: The Case of the US and the End of Nuclear Testing.** March 2023. York IND Working Paper#2.

Mikhail Kupriyanov. **Prohibition Treaties and Irreversibility**. March 2023. York IND Working Paper#3.

James Tegnelia. **Disarmament and Reversibility: A Case Study of the Denuclearisation of the United States Army.** March 2024. York IND Working Paper#4.

Patrick O'Sullivan. **Irreversibility Considerations in the Decommissioning of Fissile Material Production Facilities for Nuclear Weapons: Marcoule and Pierrelatte.** March 2024. York IND Working Paper#5.

Research Reports

Nick Ritchie. **Irreversibility and Nuclear Disarmament: Unmaking Nuclear Weapons Complexes**. March 2023. York IND Research Report#1.

Andy Stirling and Phil Johnstone**. Illuminating the 'UK Nuclear Complex': Implications of Hidden Links between Military and Civil Nuclear Activities for Replacing Negative with Positive Irreversibilities around Nuclear Technologies**. March 2024. York IND Research Report#2.

Nick Ritchie and John Walker. **Irreversibility and Nuclear Disarmament: The Case of Denuclearising the Royal Air Force**. April 2024. York IND Research Report#3.

UNIVERSITY of York

york.ac.uk

Department of Politics and International Relations