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The Protection of Historic Rocket and Missile Sites

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Over 25 years ago, the fall of the Berlin Wall and the subsequent disintegration of the military threat posed by the Soviet Union and her allies led to the most dramatic reduction in defence spending and military infrastructure since the end of the Second World War. Large numbers of previously top secret missiles and their launchers were scrapped; some became available for static display and were acquired by public museums and even private collectors. In addition to the mass disposal of hardware many hundreds of missile research, storage, and deployment sites were declared surplus to requirements.

In 1993 Professor London published a paper in the BIS Journal on the challenges of preserving space related historic sites, and in particular those related to the US manned space flight [1]. In England, Historic England has been working to protect key Cold War era sites which include a number of missile research and deployment sites. This article reviews the protection of rocket and missile sites in England and sets these against efforts in Europe and further afield to preserve and present this often neglected aspect of rocket history.

Introduction

Modern rocket technology is less than a century old, yet documentation relating to countless key projects is partial and in some cases absent. In Germany many of the early research sites, such as, Kummersdorf and Peenemünde, lay in former East Germany where documents, test equipment, rockets and missiles that survived the war were spirited away to the Soviet Union. This denied knowledge of these systems both to western rocket scientists and engineers and until recently historians of technology. In the Cold War research establishments the historical value of records relating to abandoned or superseded projects was rarely appreciated, or destroyed to save secure storage costs. Given the incomplete surviving documentation relating to early rocket history, the physical evidence of the pioneering test stands are both an important source of evidence and monuments to these early endeavours. Even where design drawings survive an archaeological analysis of the remains may reveal undocumented modifications. Likewise, rockets and missiles held by museums, and perhaps buried fragments, provide unique sources for design history and material science studies.

Beginnings

In the early nineteenth century Britain was the first western European power to use black powder war rockets when they were famously used to bombard Copenhagen and Fort McHenry, Maryland. These Congreve, and later Hale, rockets were widely adopted by the other major powers and remained on the list of British warlike stores until 1919. No traces survive of the early black powder rocket factories; though examples of rocket heads have been recovered from the Maplin Sands off the Shoeburyness ranges, Essex, and a number are displayed in Smithsonian Institution, Washington DC [2]. In the midst of the re-equipment of Britain's armed forces during the 1930s the use of rockets was reconsidered and research into new forms was entrusted to Dr Alywn Crow of the Armaments Research Department at the Royal Arsenal Woolwich, and specifically to its Ballistics Branch under Dr H J Poole. It was envisaged that the principal uses of the rockets, or un-rotated projectiles, would be for anti-aircraft defence, long-range attack, air combat, and assisted aircraft take-off [3]. To provide the project with the necessary accommodation a late nineteenth century Mobilisation Centre, Fort Halstead on the North Kent Downs, was purchased. In 1938, under the directorship of Dr Alwyn Crow it became the separate Projectile Development Establishment. To support the project the fort was adapted to new uses and offices, workshops, stores, and explosives handling areas were constructed. One of the most remarkable survivals is a building designed to fill rocket bodies with the propellant cordite (Fig. 1). A design drawing dated February 1938 identified it simply as 'New Building'. An early suggestion was that the end of a 9 foot (2.74m) tube would be closed and filled with a molten, sticky cement into which the cordite charge would be pushed. No contemporary manuals survive describing its operation, but from analysis of the building it appears that rocket bodies were to be held vertically for filling in one of four bays (Fig. 2) [4]. It's uncertain if the building was ever used for its intended function and it later earned the nickname of 'Poole's Folly' [5]. It, nevertheless, represents the earliest surviving, purpose-built rocket related building in England and Britain's first steps to manufacture modern missiles. In 1940, threatened by possible German invasion the headquarters for the rocket work was moved to Aberporth in mid-Wales, but by 1941, as the invasion and bombing threats receded, the focus of the work returned to Fort Halstead [6]. Aberporth was retained and became an important missile test range.

Wartime Developments

The use of solid fuel, cordite propelled un-rotated projectiles is well-known; a forerunner to today's anti-missile systems they were fired in batteries against the pilotless V1s, in so-called mattress bombardments in advance of D-Day, and they were

Fig. 1 Fort Halstead, Kent, Experimental filling shed F11, this building was associated with the pioneering work of Alwyn Crow and is the earliest surviving purpose-built rocket assembly building in England, Listed Grade II. (© Historic England DP060536)

Fig. 2 Fort Halstead, Kent, Experimental filling shed F11, interior showing the vertical filling bays. (© Historic England DP060548)

slung below the wings of fighters for air to ground attacks. Less recognised were the wartime British experimental guided weapons programmes; few historic records of these wartime research establishments survive [7]. By the end of the war the most advanced project was Brakemine, a radar beam riding missile powered by cordite rocket motors, developed by the Army experimental workshops at Park Royal and A C Cossor Ltd [8]. Its main test site was at Walton-on-the-Naze, Essex, which has largely been lost to coastal erosion; a single Brakemine survives (Fig. 3) [9]. The first test round was fired in September 1944 and a contemporary photograph shows a rotating mount probably adapted from an anti-aircraft gun with a launch rail in place of a barrel [10]. The Flame Warfare Establishment, Langhurst, West Sussex, investigated a liquid fuelled assisted take-off unit, 'Lizzie', for Wellington bombers. The test firings were from a simple steel-framed, corrugated-iron clad Dutch barn with a crude earth-dug flameway to direct away the efflux gases [11].

A more ambitious project to develop a Liquid Oxygen Petrol Guided Anti-Aircraft Projectile (LOPGAP) was co-ordinated by the Armament Design Department. Its main test site was to the north of Aberporth at the mouth of the River Dovey at Ynyslas. Here the concrete foundations for the launch ramp, a detached brick camera position and the footings of another survive (Figs. 4 & 5). Further remains lie within the sand dunes.

Two other smaller projects were also begun towards the end of war an air-to-air missile, Little Ben (Longshot), sponsored by the Royal Aircraft Establishment and a surface-to-air missile Stooge, developed by Fairey Aviation. It is not known if any of their test infrastructure survives.

The Late 1940s and Westcott

In the aftermath of the war, Britain was bankrupt and a rocket

Fig. 3 Walton-on-the-Naze, Essex, most of the experimental establishment has now been lost due to coastal erosion. (© Historic England RAF_106G_UK 1673 28 July 46 F/20/540 Sqdn frame 3172)

Fig. 4 Ynyslas, Dyfed, the footings of the launch rail for the LOPGAP test bed. (© Wayne D Cocroft)

Fig. 5 Ynyslas, Dyfed, wartime observation post for the remote filming of test firings. (© Wayne D Cocroft)

programme on the scale of the German V2 was unaffordable. But, a high priority was given to the development of guided weapons that were fast enough to hit high flying jet aircraft, potentially carrying atomic weapons. Many post-war British rocket research programmes were inspired by wartime German projects. Technical knowledge was transferred through the physical capture of rockets and missiles and by inviting rocket scientists and engineers to work in the United Kingdom. For a time after the war the staff at Fort Halstead was engaged in the evaluation of German equipment and prisoners of war were employed translating technical manuals. Information on the rocket research sites and specialised equipment was harder to acquire with most of the more significant research sites lying within the Russian occupation zone. Nevertheless, as the 1950 notes of Walter 'Papa' Reidel, a former Kummersdorf and Peenemünde engineer then employed at Westcott, reveal that the rocket scientists brought considerable knowledge of the test facilities with them [12]. In his notes he sketched the combustion test stand at Kummersdorf, which Werner von Braun had used during his doctoral research (Fig. 6). A careful comparison with this drawing and the surviving test stand reveal some discrepancies and illustrates the importance of being able to compare documentary sources with surviving sites and artefacts.

One significant change in the design of British test stands, probably inspired by German procedures, was the adoption of armoured direct observation windows adjacent to the firing points in contrast to British wartime stands that tended to rely on remote observation and recording by cine cameras. Direct observation was employed in the early, and now lost, test stands at Farnborough and Waltham Abbey. At the latter site an early 20th century cordite magazine was converted into a rocket motor proof stand by constructing a T-shaped control room within it with two firing pits viewed through armoured windows. Within the firing pits slotted metal wall bars were used for mounting test equipment, a feature also found in 1930s stands at Kummersdorf; a similarity of design that suggests a direct technical transfer of German practice. At the Rocket Propulsion Establishment Westcott, Buckinghamshire, the German link is even clearer where the January 1947 design drawings called the earliest tests stands the 'German emplacements' (Fig. 7). These were used to develop rocket assisted take off units, such as the Walter Werke hydrogen peroxide 109-500 series [13].

It was in one of these stands in 1947 that there was a devastating explosion of a 109/510 RATO unit resulting in the deaths of the leader of the German team, Dr Johannes Schmidt, who had been in charge of powerplant for ME163, and two British technicians. One of the consequences of this accident was the abandonment of direct observation and the return of remote observation via a mirror. In the 'German emplacements' the armoured windows overlooking the test bays were removed and their openings blocked (Fig. 8). New windows were then cut to enable the tests to be observed indirectly using a mirror

Fig. 6 Kummersdorf, Brandenburg, it was in this test stand that Werner von Braun undertook his phd research. The design of the with separate fuel and oxidant bays, water-cooled efflux ducts, and an adjacent control and direct observation room set the basic design for many subsequent test stands. (© Wayne D Cocroft)

Fig. 7 Westcott, Buckinghamshire, rear of test stand C showing the oxidant and fuel bays, entrances to the monitoring rooms, and drains for removing unspent fuel and cooling water, Listed Grade II. (© Wayne D Cocroft)

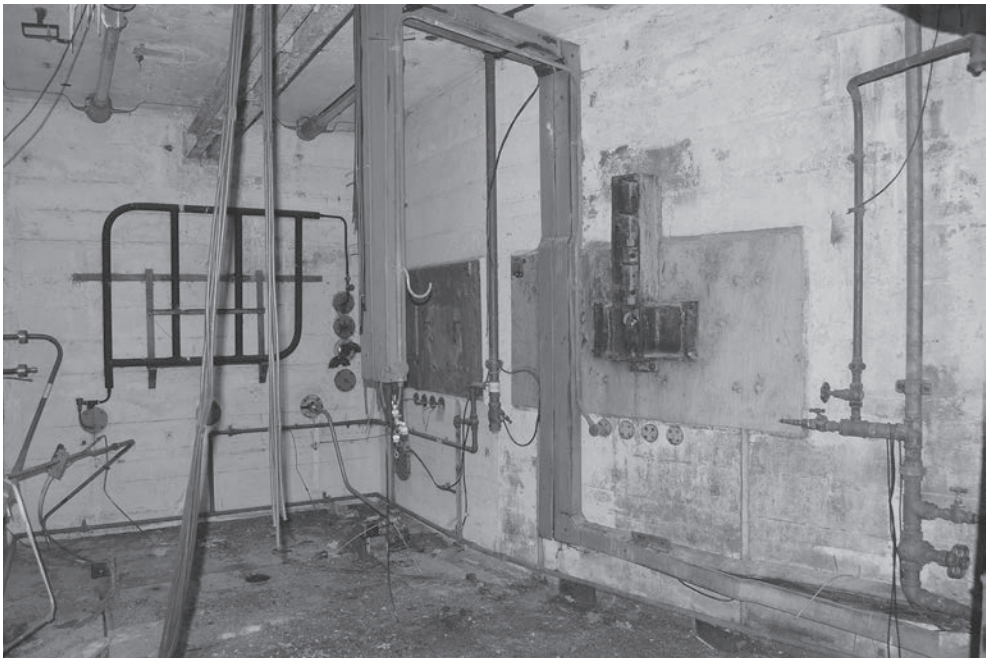

Fig. 8 Westcott, Buckinghamshire, Stand C, showing the observation window openings blocked after the 1947 explosion. (© Wayne D Cocroft)

mounted on a stand. In acknowledgment of their position in the transfer of technology and links through their design and associations with German scientists to the pioneering work at Kummersdorf and early British post-war research the four earliest stands have been listed at Grade II*.

In the late 1940s when two new stands were constructed at P Site for the research test vehicles the control and observation room was placed in a detached monolithic bunker that would provide protection against an accidental explosion. Both the P site test stands are listed at Grade II. In addition to the relatively sophisticated German inspired stands the Dutch barn from Langhurst was also moved to Westcott, where its footings remain.

At the end of the 1950s K site was developed for the test firing of large solid propellant rockets. These sites are simpler in form to the liquid propellant stands with their requirement to keep fuel and oxidant storage and handling carefully separated, and the need for complex drainage system to carry away unspent propellants. It's unclear if the K site stands were built to support a particular programme, or if they were constructed for more general solid propellant research. K1 (Fig. 9) was designed for firing inverted rockets to allow for the observation of their plumes. While, K2 (Fig. 10) was designed for horizontal firings with a detached control and monitoring room, firing chamber and a refractory concrete wall to deflect the motor's plumes. Both these stands are listed Grade II.

Fig. 9 Westcott, Buckinghamshire, stand K1 for firing inverted motors, Listed Grade II.
(© Historic England BB94/04860)

Fig.10 Westcott, Buckinghamshire, stand K2 for horizontal firings, Listed Grade II.
(© Historic England BB94/4862)

Westcott was at the heart of the United Kingdom's missile research programmes and the protected test stands provide a tangible link to the transfer of pre-war German technology as well as ground breaking post-war British research.

Other Places

In addition to the main government establishments it was planned to undertake guided weapons research at Foulness on the Armament Research Department's range at Shoeburyness, Essex. In 1945, a protected, brick control and monitoring building with steel shuttered windows was built. It's unclear if it was ever used for its intended function and from 1947 it was devoted to nuclear weapons related trials. Typically initial research into rocket propellants was carried out at the Royal Arsenal Woolwich and the Chemical Research and Development Department, Waltham Abbey, while manufacturing was undertaken in the Royal Ordnance Factories. One of the challenges in developing larger diameter solid motors was the difficulty in extruding large diameter charges. To master this technology a captured German press that could extrude charges up to 20.6in (0.52m) was installed at Royal Naval Propellant Factory Caerwent, and led to the development of a 22.5in (0.57m) press, at least one of which was installed at Bishopton, Scotland [14]. At Caerwent a test bed for the Gosling booster motors used for Thunderbird and Bloodhound surface to air missiles has been listed by Cadw [Welsh Heritage Agency]. At Aberporth, an experimental rolling platform used in the contemporary naval surface to air Seaslug programme is also protected. Also surviving from this era are the remains of the experimental range on the Isle of Anglesey for test firing the army's Thunderbird surface to air missile. The Royal Aircraft Establishment also established an out station at Larkhill, Wiltshire, to develop guided weapons for use by the Army. In the private sector at Ansty, Coventry, Armstrong Siddeley Motors created a crude test bed as early as 1946. The following year a more substantial test house 'No.50' was constructed. This was probably an indigenous British design as it is suggested that it was designed before Harry Sunley returned from his service with British Overseas Information Service in Germany. It was later used for other purposes, but enough of the structure remained to be measured to offer a reconstruction of its original form [15]. De Havilland also constructed test beds at Hatfield.

Bloodhound Surface to Air Missiles

In 1956, in recognition of new threats of high flying jet bombers and unstoppable missiles Britain's fixed anti-aircraft gun system was stood down. Two years later to defend the nuclear deterrent bases Bloodhound Mark 1 surface to air missiles were deployed on eleven sites in the East of England (Fig. 11). The control equipment of this second generation surface-to-air system was essentially dependent on glass valve technology that was fragile, heavy, power hungry, and required a dedicated cooling plant to disperse the heat generated by its electrical equipment. It was a system literally rooted to the ground.

But, it was known that its radar guidance system was susceptible to jamming, and the first system was quickly superseded by the Bloodhound Mark II that was less vulnerable

Fig. 11 RAF Woolfox Lodge, Rutland, Bloodhound Mark I surface to air missiles. (Bristol Aircraft)

to electronic blocking, easier to maintain, semi-mobile and air portable, although it might take a unit about a day to mount up. The new system was initially deployed in the United Kingdom, but then transferred to defend British bases in Germany. In the late 70s with perceived threats from a new generation of Soviet fighter bombers, six units were returned to the United Kingdom. Typical requirements were for simple concrete platforms for the missile launchers, target radars and control cabins (Fig. 12). By the 1980s, as Bloodhound became a permanent feature, on some sites small brick work shops were added. The final withdrawal of Bloodhound in 1991 marked the end of fixed surface-to-air defence systems in the United Kingdom and today the highly successful Rapier family is a fully mobile system (Fig. 13). The concrete footings and ancillary buildings survive on a number of former Bloodhound sites.

Bloodhound missiles enjoyed some export success and this is reflected in traces of their sites in Sweden, Switzerland, Singapore and Australia, as well former British bases in Germany. At Gubel BL64 near Zug, Switzerland, a British supplied Bloodhound missile site, with its Scorpion Type 87 radars has been preserved and the missiles are periodically brought out from their shelters [16].

Blue Streak Intermediate Range Ballistic Missile

The United Kingdom's most ambitious Cold War missile programme was the Blue Streak intermediate range ballistic missile, with a range of around 1,500 miles, it had the potential to threaten Moscow. Blue Streak was based on the United States' large liquid propellant fuelled missile Atlas with engines developed by Rocketdyne and its airframe manufactured by Convair. As in all areas of technological transfer production of the missile was far more challenging than manufacturing a copy. British material and production standards differ

Fig. 12 RAF Barkston Heath, Lincolnshire, footings for a Bloodhound Mark II launcher showing cable channels that led back to the control cabins. (© Wayne D Cocroft)

Fig. 13 Rapier missile and tracking unit, a modern fully mobile surface to air missile system requires little if any fixed infrastructure. (© Wayne D Cocroft)

from those of the United States, and during its development each subsystem required rigorous testing before they were assembled for full vehicle test firings. As the design evolved important modifications were introduced notably the use of two engines instead of the three used by Atlas and a redesign of the kerosene tank that allowed it to be self-supporting while standing vertically. Characteristic of many Cold War weapons projects the development of the missile was a collaboration between the government research establishments and private industry. The principal contractor was the de Havilland Aircraft Company that was responsible for the airframe, with the majority of activity split between its factories at Stevenage and Hatfield with support from its Farnworth and Lostock works. The engines were developed and manufactured by Rolls-Royce at Derby and Ansty, and its inertial guidance system was by Sperry Gyroscope, Bracknell; many other suppliers provided sub-systems, ground and test equipment.

To support the Blue Streak programme a complex infrastructure of research, test and manufacturing facilities were required. Missile assembly was centred on de Havilland's Stevenage works, a recently completed factory built as a machine shop for the Comet airliner, was extended for final missile assembly work and to accommodate the electronics laboratories and trials teams. The factory survives and is now occupied by Airbus Defence and Space Ltd, Europe's leading spacecraft manufacturer. At its nearby Manor Road, Hatfield, factory work was carried out on the autopilot, hydraulics and ground support equipment. A large handling frame was also built for flow tests and a prototype launcher, other structural tests were carried out by the Royal Aircraft Establishment, Farnborough, and the Hunting Aircraft Company, Luton. Blue Streak's engines were based on those developed by Rocketdyne for the Atlas missile. Such was the urgency to start the project that Rolls-Royce modified one of the late 1940s test stands at Westcott, P2, to test its prototype RZ1 engine; other facilities were also used for component testing (Fig. 14).

Spadeadam Rocket Establishment

For full vehicle test firings the missile was loaded with about 87 tons of liquid oxygen and kerosene, which potentially represented a major hazard that demanded a remote range with large safety distances. The Home Office insisted on a distance of four miles from any habitation. After a number of existing military ranges were considered it was decided to build a dedicated range at Spadeadam Waste, Cumbria. Located on Forestry Commission land to the north of Gilsland and Hadrian's Wall, it's one of the most desolate places in England, naturally a treeless landscape of peat bogs and rough sheep grazing. To the rocket engineers it offered isolation, solid bedrock to support the test stands, and ready access to water for cooling the stands.

The establishment was created with the intention that all the completed missiles would be transported by road from Stevenage for test firings; firstly to assist in the development of missile and then each of the 60 operational missiles were to be proof fired before being emplaced in underground launchers. Its remoteness created many challenges for the construction teams, access to the area was along small rural roads and to cross the peat bogs rafts of beech wood were laid. To accommodate the workforce a large temporary navvy camp was built at its entrance.

Although the range covered about 3000 hectares operations were concentrated in five areas separated by generous safety distances; their functions were administration and rocket assembly, a British Oxygen Corporation production area, Component Test Area, Engine Test Area, and the Missile Test Area. On arrival at Spadeadam the missiles were taken to a large assembly hall for checking and final assembly work. Other facilities in this area provided small workshops, accommodation, welfare and administrative functions for the range. The test programme required huge quantities of liquid oxygen and nitrogen and about 100m to the north of the administration area the British Oxygen Corporation (BOC) built a liquid air plant for the production of liquid oxygen and liquid nitrogen. Although, the plant has been demolished its ruins may be used to explain the basic production process.

Many of the pumps within the missile ran at very high pressure and also used the oxidant liquid oxygen with the associated hazard that any component failure might result in a small explosion. About 300m to the north of the BOC area was

Fig. 14 Westcott, Buckinghamshire, P2 a late 1940s test stand was converted for Blue Streak engine testing, Listed Grade II. (© Wayne D Cocroft)

the Component Test Area (CTA). At its centre was a reinforced concrete control room surrounded by small test cells, including two chambers driven by turbo-jets. The control room also overlooked a bank of detached test cells with fuel and oxidant tanks on their roof.

A further 1.8km separated the CTA from the Engine Test Area (ETA), this was as its name suggests used for test firing engines and its location at Priorlancy Rigg made good use of an east to west escarpment. The engines were mounted vertically with a propellant and oxidant tank in a similar configuration to the assembled missile. The upper clean area was used for manoeuvring engines into position on the stands and a lower dirty area was dedicated to spillways to carry away the cooling waters and unspent kerosene. Operations were controlled and monitored from a remote protected control room and firings were observed through submarine -like periscopes mounted in its roof. The control room was connected to the test stands by an underground instrumentation duct 381 m in length and containing 8,000 instrumentation and control cables. A Treasury official considered the duct to be one of the few extravagances in the design of the establishment [17]. Three of the four test stands were based on those used on Rocketdyne's Californian test site. Their open design proved unsuitable for the wild Cumbrian climate and they were soon covered to provide some protection for the personnel and test engines. Another drawback of this design was brittleness in the steel caused by liquid oxygen vapour. To guard against failure during test firing the hollow legs of the stands were filled with concrete. When a fourth stand was required a novel design in pre-stressed concrete which was better able to resist low temperatures was proposed by Dr Francis Walley, then employed by the Ministry of Works. Unfortunately, this test stand has been demolished, although amongst its rubble its steel reinforcing wires are clearly visible and the engine mounting block. Another innovative feature of this stand was the use of epoxy to bond steel to concrete [18].

The two largest test stands on the ranges were at Greymare Hill about 3km to the north of the ETA (Figs. 15 & 16). They too made use of a natural escarpment, the two stands, connecting road, and support buildings set along the 310m contour line. The facilities here were identical to the launch sites being constructed at Woomera, Australia, and were used to develop the ground support equipment and operational procedures that would be employed used during live test launches. As discussed above it was originally intended to use Spadeadam to develop the test vehicles and then to proof fire the service rounds. To meet this requirement and the timetable for deploying the

Fig. 15 Spadeadam, Cumbria, Greymare Hill, C3 test stand, flameway and effluent settling pool, scheduled.
(© Historic England 17819/16)

Fig. 16 Spadeadam, Cumbria, Greymare Hill, C2 test stand, when the Blue Streak missile was cancelled in April 1960 this stand was left unfinished, scheduled.
(© Historic England AA94/2010)

missiles it was originally intended to operate two stands C2 and C3 simultaneously. When the Blue Streak missile project was cancelled in April 1960, construction work was suspended on C2 and C3 was later completed for use by the European Launcher Development Organisation (ELDO) for the development of its Europa launch vehicle Europa. At Woomera, the foundations of the nearly identical launch stands LA6B and LA6A survive, although without legal protection [19].

Spadeadam was from the late 1950s until the final demise of Europa in 1973 a world class rocket research centre. However, soon after the programme was cancelled most of the specialised test facilities were demolished and the steel work scrapped. The administration area remained with the intention that it should become the headquarters for the relocated Shoeburyness proof establishment; then threatened by a proposed new London airport on Maplin

Sands. This move was cancelled and from the late 1970s the RAF began to use the range for electronic warfare training, a role it maintains.

Blue Streak Underground Launcher or Silo

Such was the urgency of the Blue Streak project that many of the different elements of the missile's development advanced in parallel. One of the most pressing issues was how the missile was to be deployed and launched. By summer 1958 the preferred option was for an underground launcher, or silo, a then untried technology. Initial trials work was carried out at Westcott and began with a 1/60 scale model mounted on a lathe, the concrete slab on which it was mounted survives. This was followed by a 1/6 scale model comprising a series of inter-locking octagonal concrete sections. These were assembled to form a mock-up of U-shaped launch chamber and a Gamma rocket motor fired within it to understand the acoustic and other effects of firing a rocket within a confined space. Due to the high temperature of the efflux gases the concrete was liable to melt and flow. To overcome this problem the concrete comprised bauxite aggregate and sika cement. Dr Francis Walley commented it was probably the most expensive concrete ever made [20]. A number of test silo segments remain scattered around Westcott, although without any formal protection (Fig. 17). The next stage was to be a full-scale proto-type at Spadeadam. To reduce the necessity for a deep excavation the experimental underground launcher was to be placed in a valley with only about one fifth of the silo below ground. Such an arrangement would have allowed the missile to be loaded from a bridge leading from the crest of the valley side. A similar arrangement was proposed for Woomera, Australia, where the test silos were to be sited on the side of a ravine. Blue Streak and its silo projects were cancelled in April 1960. In common with many abandoned defence projects there are few surviving documents relating to the silo research programme. Archaeological survey work at Spadeadam confirmed that the project had started and the location of the proposed silo (Fig. 18) [21]. Another important element of the silo story was revealed by a session at a British Rocket Oral History Programme conference when Dr Barrie W A Ricketson, former head of Gas Dynamics, Rocket Propulsion Establishment, recounted a visit to the United States to brief the Americans on this work. A historian of the Titan missile programme summed up the significance of the British design work when he commented that 'Blue Streak was the free world's first in-silo weapon system concept' [22]. The resulting Titan II missile silos remained operational until 1987. This was a ground breaking and world class technology and its significance is recognised by the scheduled status of the abandoned test site excavations at Spadeadam.

Spadeadam represents not only a high point of British 1950s technical achievement, but since the loss of the US Rocketdyne stands the site is a unique (western) survival from the era of large liquid fuelled rockets. It may also be seen as a place that characterises 1950s Britain; the white heat of technology and what Professor David Edgerton has dubbed the British warfare state [23]. In acknowledgement of their international rarity and the technological achievement that they represent the foundations and unused buildings of the liquid air factory and test areas are protected as scheduled monuments. A surviving Blue Streak missile, F1, an electrical mock-up, and its handling frame in the main car park are listed Grade II (Fig. 19) [24].

Fig. 17 Westcott, Buckinghamshire, sections of the one sixth scale underground launcher model. (© Historic England BB99/04750)

Fig. 18 Spadeadam, Cumbria, excavation for the full size underground launcher mock-up, Scheduled. (© Wayne D Cocroft)

High Down Test Site, The Needles, Isle of Wight

Also associated with the Blue Streak programme was the experimental test vehicle *Black Knight* whose function was to launch test re-entry heads. The design study for the rocket was undertaken by the Royal Aircraft Establishment and production carried out by Saunders Roe Ltd at their Osborne Works, Cowes, Isle of Wight. It used a peroxide/kerosine engine, Gamma, developed at Westcott and manufactured by Armstrong Siddeley [25]. A second stage solid propellant *Cuckoo* was used to propel the test warheads on their re-entry journey. To support the project Saunders Roe occupied offices at the former Royal Naval College at Osborne House and constructed test stands at the Needles. There they took over a recently abandoned Victorian coastal battery and a number of its casemates were converted to house recording equipment. The two test stands occupied a spectacular position above the chalk cliffs of the Needles and made use of a natural bowl-shaped hollow. The two stands were sited below the crest with the efflux channelled down the bowl towards the cliff edge. The conversion of parts of the fort and the design of test stands and new support buildings were designed by John Strube, a private architectural practice

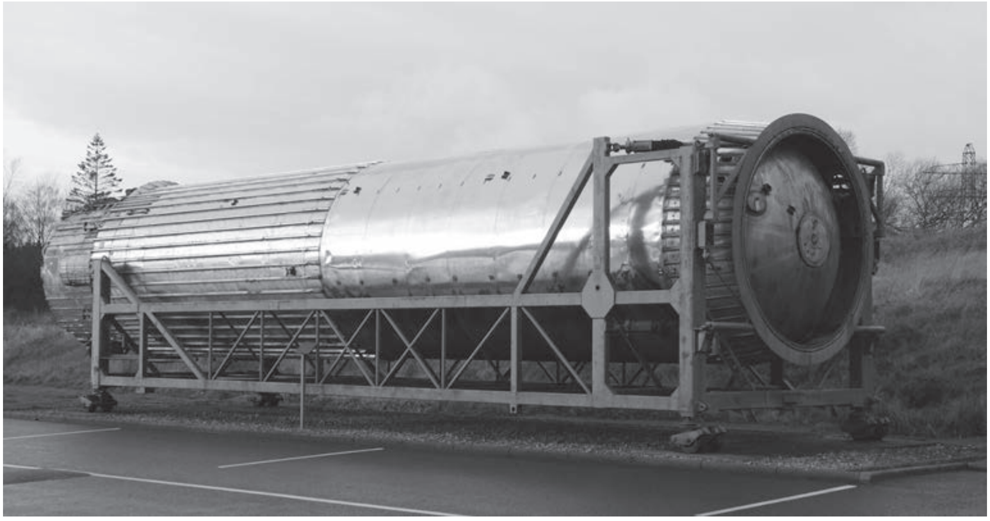

Fig. 19 Spadeadam, Cumbria, a Blue Streak test vehicle, Listed Grade II. (© Wayne D Cocroft)

(Fig. 20). The Needles fulfilled a similar role to Spadeadam and rockets were proof fired before being shipped to Woomera for live launches.

After the completion of the *Black Knight* project work began on a satellite launcher *Black Arrow*. On 28th October 1971 a *Black Arrow* rocket launched the British built satellite *Prospero*, the only all-British launching system to place a satellite in orbit [26]. After the cancellation of the *Black Arrow* project there was an unsuccessful attempt to market the site as a general industrial test site. Shortly afterwards the fort and rocket research establishment were acquired by the National Trust and most of the facilities within the test area demolished. Over the past decade there has been new interest in the rocket research and displays within the fort tell the story of the rocket programmes. The test stands survive and are the only publicly accessible monument to Britain's entry into the space age.

Thor

The launch of the Soviet satellite Sputnik in 1957 raised fears in the West that they might also be able to deploy a missile tipped with a nuclear warhead. To counter this threat 60 United States Thor intermediate range ballistic missiles were placed in England in groups of three on 20 airfields. The missiles and their infrastructure were provided by the United States, while the most of the ground crews were RAF personnel with the exception of one USAF officer who held one of the launch keys. It was one shot system and this along with the need for speedy deployment resulted in a light infrastructure (Fig. 21). It comprised a roughly cruciform shaped hardstanding with a sliding shed mounted on rails to cover the missile, on the other arms were positions for the fuel and oxidant trailers, two L-shaped concrete walls provided protection for the launch control trailers (Fig. 22). Famously, during the October 1962 Cuban Missile Crisis, 59 out of the 60 missiles were raised to alert. Two sites at North Luffenham and Harrington are listed.

After their withdrawal in 1963 as an operational missile system Thor was used as a satellite launch vehicle. Launch Complex 10, Vandenberg, California, from where many Thor launches were controlled has a similar infrastructure to the UK Thor sites; it is now a registered historic landmark. The Thor sites remind us of one of the most dangerous periods of the

Fig. 20 The Needles, Isle of Wight, the footings of the Saunders Roe test stands, scheduled. (© Wayne D Cocroft)

Fig. 21 Harrington, Northamptonshire, Thor missile pads, Listed Grade II. (© Historic England 21824/23)

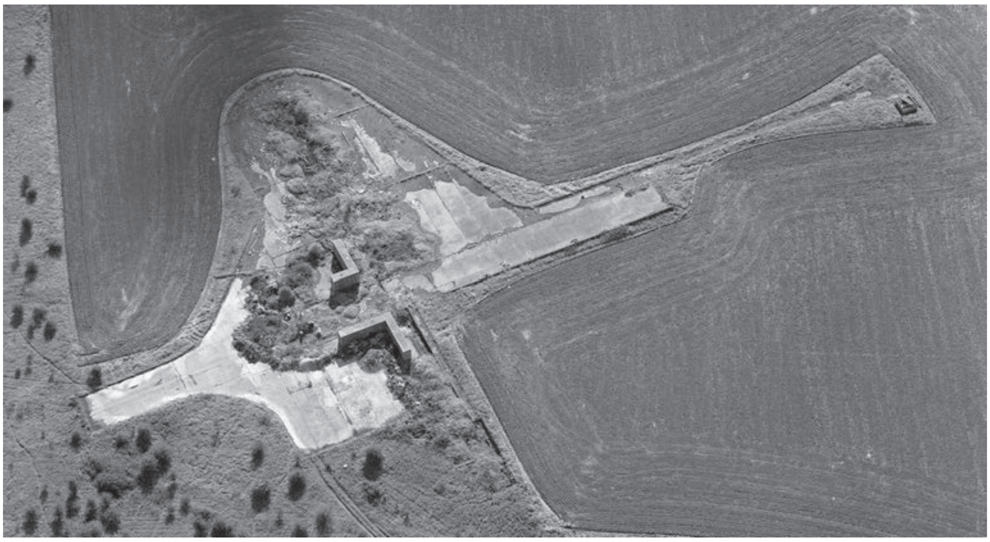

Fig. 22 Harrington, Northamptonshire, Thor missile pad showing the two L-shaped walls that protected the launch control trailers, Listed Grade II. (© Historic England 21825/04)

Cold War. In Cuba, traces of the missile sites that sparked off the 1962 crisis may also still be found. These include a concrete launch pad bases, prefabricated missile and warhead hangars, and pierced steel track matting recovered for building materials [27].

Blue Steel

Before the V-force of manned jet bombers carrying nuclear weapons became operational it was recognised that improving Soviet air defences would soon render high level bombers vulnerable to attack. To extend their operational life it was proposed to develop an air-to-surface stand-off missile that could be fired around 100 miles from its target. Code-named, Blue Steel, the principal airframe contractor was A V Roe & Co, Woodford, Cheshire, while Bristol Siddeley, Ansty, developed its Stentor engine. In common with other contemporary defence projects the private manufacturers worked closely with the government research establishments. At Westcott, a purpose-built test stand, Site E, was constructed to test the prototype Stentor engines (Fig. 23). Typical of many test stands it was reused for later programmes, most notably the manoeuvring motors for the Chevaline warhead, nevertheless, enough of the original form of the test stand remained for it to be listed at Grade II. Indeed, reuse by successive projects may add to the historic interest of a structure. Given, sufficient safeguards in the future protected test stands may find new uses and contribute to new scientific endeavours.

Blue Steel was deployed on two RAF stations, Scampton, Lincolnshire, and Wittering, Peterborough UA, and on both sites dedicated infrastructure was put in place to handle the missiles and their hazardous oxidant high test peroxide. At Scampton, the frames of two wartime T2 hangars were joined to create a storage hangar for the missiles, now demolished, and a remote fuelling building was constructed. At Wittering a double-storey structure was built to house the missiles, in the lower storey were garages for the specialised AEC Mandator transporters and above the environmentally controlled missile storage areas. This building represents a specialised purpose-built structure designed to handle and store missiles and the final nuclear deterrent system carried by the RAF; the building is listed at Grade II (Fig. 24).

Rapier

Air defence missile systems may be used in point defence of key potential targets facilities, such as airfields, command

Fig. 23. Westcott, Buckinghamshire, Stand E originally built for testing Blue Steel's Stentor engines, Listed Grade II. (© Wayne D Cocroft)

Fig. 24 RAF Wittering, Peterborough UA, purpose-built Blue Steel storage facility with garages for AEC Mandator missile transporters, Listed Grade II. (© Historic England AA99/09838)

centres, and cities, or as mobile systems deployed to defend field forces. Evolving missile technology, tactical requirements, and especially miniaturisation through the adoption of integrated circuits with more robust and compact control equipment led to smaller missiles that were designed to be mobile, or semi-mobile. This in turn resulted in less permanent infrastructure that has left fewer tell-tale traces of their deployment. To the general visitor their concrete and asphalt hardstandings may appear no more interesting than an average car park. The British Rapier air defence missile developed in the late 1960s is an entirely mobile system that can be set up in any open area (Fig. 13). During the 1980s as part of the Trident missile deal, Britain agreed to provide the air defence for the USAF airbases in the United Kingdom. Mobile systems, such as Rapier, leave few if any physical traces, at RAF Upper Heyford, Oxfordshire, the missiles were positioned in crude earthwork and sandbag emplacements, most of which have disappeared. The control of the missiles was directed from the airfield's hardened battle headquarters, where the Rapier unit's command room survives within the scheduled structure. Elsewhere, on the Rapier missile home bases, such as the recently vacated airfield at Kirton in Lindsey, Lincolnshire, specialised missile storage buildings, vehicle and trailer wash-down facilities, and training domes may be found (Fig. 25). These were similar to wartime facilities for training air gunners where moving targets were projected onto the dome.

Ground Launched Cruise Missiles

With the exception of the re-introduction of Bloodhound air defence system no new missile sites were built in the United Kingdom during the 1970s. However, by the end of the decade there were increasing Cold War tensions as the Soviet Union deployed mobile SS20 Saber missiles into Eastern Europe, potentially upsetting the balance of power, a further deterioration in relations occurred with Christmas 1979 Soviet invasion of Afghanistan. In this new and dangerous phase of the Cold War the NATO hardening programme continued apace to protect vital assets and a new generation of western tactical missiles systems, ground launched cruise and Pershing II missiles, were introduced into Western Europe.

Fig. 25 RAF Kirton in Lindsey, Lincolnshire, Rapier training dome used to practice tracking targets. (© Wayne D Cocroft)

To house the cruise missiles six standard shelter complexes GLCM alert and maintenance area (GAMAs) were built across Europe in the United Kingdom, Belgium, Sicily, Italy, and Germany. These were heavily hardened structures designed to survive a near-miss. Cruise was a fully mobile system and the shelters may be seen as heavily protected garages (Fig. 26). In each complex one shelter was designated as a Quick Reaction Alert (QRA) and was kept on permanent stand-by with integral crew accommodation and in extremis missiles could be launched from the adjacent concrete hard standing. Each of the shelters originally protected a flight of four missile launchers, each with four missiles, and two launch control centres (Fig. 27). The complexes were protected behind a triple fence and movement sensors. Also associated with the deployment of cruise missiles was a USAF computer centre housed in a refurbished, three-storey, wartime bunker at Daws Hill, Buckinghamshire. This is listed at Grade II*. Amongst its functions was the calculation of the flight programmes for the missiles. Cruise technology also reflected the massive step change in defence spending of the Reagan-Thatcher era that the east was unable to match and arguably broke the Soviet Union.

The End of the Cold War

Prior to the 1980s the usual fate for obsolete missile sites was for their metal components to be sold for scrap, while their remaining concrete hardstandings might make convenient parking areas

Fig. 26 Greenham Common, Berkshire, the whole of the GAMA complex is protected as a scheduled monument. (© Historic England 24638/003)

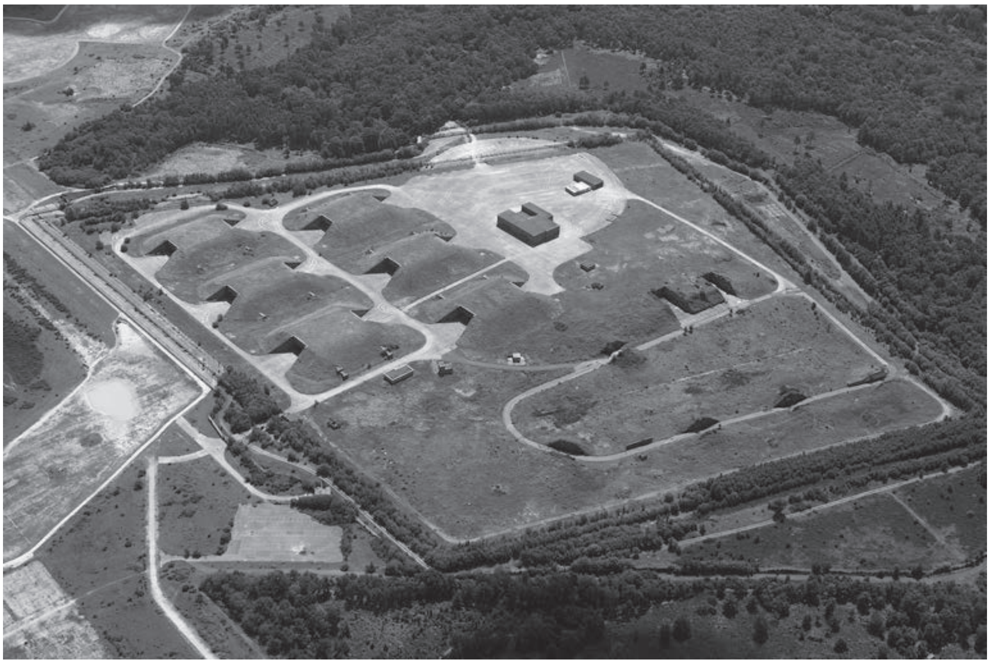

Fig. 27 Pima Aviation Museum, Tuscon, Arizona, the main vehicles from a 1980s cruise missile convoy, including a launch control centre and a transporter erector launcher. (© Wayne D Cocroft)

for agricultural machinery. After the rapid arms build-up of the early 1980s the two superpowers drew back and through the 1987 Intermediate Nuclear Forces (INF) treaty they undertook to remove a whole class of nuclear weapons from Europe. This provided for the elimination of certain classes of missiles and their launchers, although provision was made for a limited number of demilitarised items to be placed on public display [28]. Another feature of the treaty was the right to on-site inspections to check the equipment had been removed and the site deactivated (Fig. 28). At Greenham Common, while its runway was ripped up as hardcore for the Newbury by-pass the right for short term inspection over the 13 year life of the treaty ensured the survival shelters and associated buildings [29].Shortly after the end of this period English Heritage recognised the significance of the site by a designating it as a scheduled monument.

International Parallels

Internationally, many examples of preserved rockets and missiles may be found in general aviation, science and technology museums. In common with the United Kingdom there are few examples of preserved rocket research establishments and deployment sites. In Germany, there are many practical and philosophical challenges in the preservation of the early rocket sites. Should they be presented as technological monuments, or as monuments to the suffering of the forced and slave labour employed within them? Some of the earliest research was carried out at Kummersdorf, 46km to the south of Berlin. Here the surviving tests stands include the one used by Wernher von Braun during his phd research (Fig. 6) and another where the A3 with its liquid oxygen and alcohol engine was developed, the precursor of the A4 or V2. In the late 1930s, from Kummersdorf the focus of attention moved to the new, large purpose-built rocket test and manufacturing complex at Peenemünde on the Baltic. This site was devastated by RAF bombing in August 1943 and at the end of the war stripped and demolished by the Soviet occupation forces. Post-war it was used as a military training area and has only become accessible since the early 1990s. An information centre has been created in the former power house, the massive liquid oxygen plant survives as a ruin

Fig. 28 Greenham Common, Berkshire, Wing Headquarters briefing room, this image taken in October 1999 shows the situation board set up in preparation for Soviet on-site inspection teams. The different coloured suspended floor inlays mark the position of removed control consoles. Listed Grade II*. (© Historic England AA003341)

and within the woods the earthworks and shattered concrete of the test stands may be traced. Adjacent to the research centre is the former Luftwaffe airfield and on its periphery the footings of the test stands for the V1 programme (Figs. 29 and 30). It was also here that the rocket-propelled ME163 was first seen by air photography interpreters.

The British air raid of August 1943 highlighted the vulnerability of Peenemünde to attack and preparations were put in place to spread V2 production across the Reich and in particular to an underground assembly factory at Dora Mittelbau, close to the town of Nordhausen in the Harz mountains [30]. Here, the production of V1s, V2s and other weapons were managed by the SS with great barbarity. Although, many rocket components remain within its tunnels, this site is maintained as a monument to those who suffered and died within its camps.

France

Initially, it was planned to launch the V1s and V2s from fixed sites in northern France. The light infrastructure of the so-called ski sites for the launch of V1s were largely destroyed by allied bombing prior to D-Day in June 1944. Subsequent launches were from semi-mobile launch sites. A number of V1 storage sites and launch sites survive, although none have yet been prepared for public presentation. At first, it was proposed to launch the V2s against Britain from two massive bunkers. At Eperlecques a huge, rectangular bunker was constructed, large enough to hold a stockpile of rockets and for them to be launched vertically through its roof. Here bombing by allied air forces halted work (Fig. 31) [31]. Equally, ambitious was La Coupole, a huge dome of concrete shielding the rocket assembly and launch area [32]. Both sites are open to the public; Eperlecques is presented as a ruin with external exhibits of military equipment. La Coupole offers a more diverse visitor experience, including a tour of the facility, displays on its history and temporary exhibitions, often on aspects of the D-Day campaign, and a 3D planetarium emphasises the scientific legacies of these wartime programmes.

The United States

In the United States, one of the most spectacular preserved missile sites is the Titan II missile silo to the south of Tucson, Arizona (Figs. 32 and 33) [33].

Fig. 29 Peenemünde, showing the section of the airfield where the V1 was developed. (Courtesy of Bob Bewley)

Fig. 30 Peenemünde, the footings for the experimental V1 launch ramp and observation bunker. (© Wayne D Cocroft)

Fig. 31 Eperlecques, Northern France, the massive bunker built for the assembly and launch of V2 rockets. Construction began in 1943, but was halted by allied bombing. (© Wayne D Cocroft)

The silo remains not only as a monument and memorial to Titan programme and the crews that manned the system, but also the pioneering work undertaken in the United Kingdom to develop an underground launcher [34]. Most of the other Titan and Atlas silos have been demolished, one has been acquired by a group of survivalists, and another filled with hazardous waste. A later generation of ICBMs is represented by three preserved Minutemen sites. The Ronald Reagan Minuteman Missile Historic Site is located in Cooperstown, North Dakota, and comprises two sites, Oscar-Zero Minute Alert Facility and November 33 Launch Facility [35]. The third site, Launch Control Facility, Delta-01, is recognised as a National Historic Site and is operated by the National Park Service [36]. On the Nevada Test Site, originally established for testing atomic weapons, 1960s trial facilities survive in the Nuclear Rocket Development Area for the Rover rocket engine and Pluto ramjet projects [37]. These features contaminated with radioactivity within a restricted test range are likely to survive until funds are found for their clearance.

In many instances the fixed infrastructure and equipment were integral parts of the system, but in very few instances have fully equipped sites passed directly from service use into active preservation. This may be due to the secrecy, lack of appreciation of historical significance, environmental legislation, or disarmament treaties that required evidence of destruction. In other instances where countries have supplied weapons systems to foreign powers at the end of their operational lives they may require their return to the originating country. Where equipment is retained it will require continuous maintenance often made more pressing by the absence of ambient warming from active electrical systems. First generation Cold War air defence missile sites were characterised by distinctive deployment sites to handle the relatively large missiles and to house bulky electronic control equipment. At Fort Barry in the Golden Gate National Recreation Area, San Francisco, the only remaining and publicly accessible Nike surface to air missile has been preserved complete with deactivated missiles and their ground handling equipment. In Denmark at Hoejerup (Fig. 34) the 1980s United States supplied Hawk missile battery site has been retained and adapted as a visitor centre for the coastal park; with a radar tower converted into a viewing

Fig. 32 Tuscon, Arizona, Titan Missile Museum. (© Wayne D Cocroft)

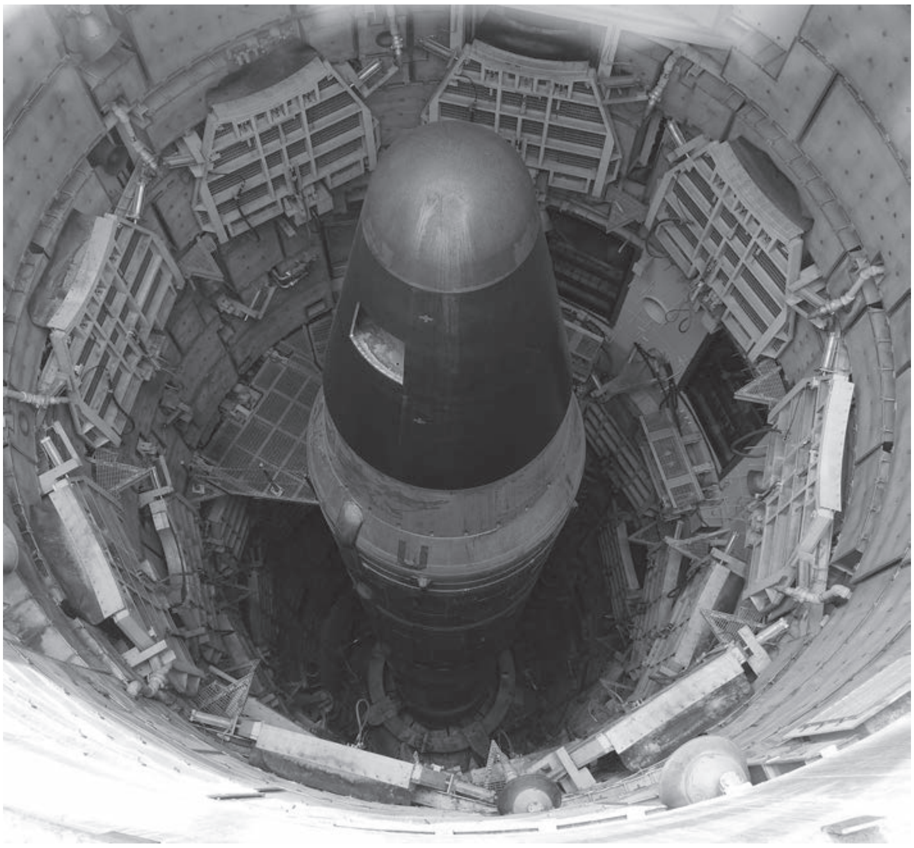

Fig. 33 Tuscon, Arizona, Titan Missile Museum, the Titan missile sits in its silo, the hole in its nose cone clearly indicating its deactivated status. (© Wayne D Cocroft)

Fig. 34 Hoejerup, Denmark, 1960s Hawk surface to air missile battery site showing the hardstandings for the fire sections. It now forms part of a coastal park. (© Wayne D Cocroft)

platform and notice boards explaining the site's former function. Nearby at Stevns Fort, a complete deactivated Hawk battery has been preserved and during the summer season the radars and missiles are positioned on their emplacements (Figs. 35 and 36).

Former Eastern Bloc Missile Sites

In former Warsaw Pact countries many examples of Cold War missile and their launchers are displayed in military museums (Fig. 37). But, many recently independent countries of central Europe have an uncomfortable relationship with the legacy of this recent past. Abandoned Soviet military bases are often remote with unknown contamination hazards and are regarded by many as reminders of an unwanted occupation. In most instances there were few local connections with their crews drawn from elsewhere in the Soviet Union. At some locations the tourist potential of these sites might ensure their survival. At Plokštinė, Lithuania, the partly dismantled early 1960s, SS-4 Sandal missile launch complex with four silos lies abandoned, with tours available through the Zemaitija National Park. In neighbouring Latvia, at Zeltini, is a contemporary derelict missile base that survives with hangars for mobile SS-4 launch vehicles and associated warhead stores.

During the latter stages of the Cold War Ukraine was home to 176 nuclear missile silos. Under the Strategic Arms Reduction Treaty (START) all of the silos, except one, were dismantled and demolished. At Pobuzke, a command centre and one of its ten silos was retained and developed as a museum. The site comprises surface buildings with exhibitions and outdoor exhibits, including a SS-18 Satan missile, a command post housed in a 12 storey capsule suspended inside a silo, and the silo for a SS-24 Scalpel missile [38].

Fig. 35 Stevns Fort, Denmark, the Cold War museum displays a number of surface to air missiles, to the left a Nike Ajax and to the right a Nike Hercules. From 1960 until the 1980s both types defended Copenhagen. (© Wayne D Cocroft)

Fig. 36 Stevns Fort, Denmark, a 1980s Hawk missile battery with its radars protected by weather covers. (© Wayne D Cocroft)

Fig. 37 Fort Czerniakow, Warsaw, SA2 Guidelines and SA3 Goa. (© Wayne D Cocroft)

Undesignated Heritage Assets

In common with many other types of buildings and structures relatively few rocket and missile test, and deployment facilities have survived, and fewer still have retained their infrastructure, monitoring and control equipment. Internationally, few have been given legal protection or made publicly accessible. In some cases archaeological traces will remain of abandoned sites, although usually stripped of salvageable material (Fig. 38). Elsewhere, sites have been deliberately removed and no more than a landscape scar may remain.

Conclusion

From this brief survey of preserved rocket and missile sites it is clear that they reflect an international technological heritage; one of science and technology, and of modern warfare. The contribution of German wartime rocket research to the post-war

Fig. 38 Altengrabow, Germany, 1980s Soviet missile store, common practice in the Soviet armed forces was for warheads and missiles to be stored separately under the control of different units. (© Wayne D Cocroft)

programmes of America, the Soviet Union, Britain and France is a familiar story. The influence of the German scientists and engineers on research practices, reflected in part by the infrastructure of experimentation, is still an under studied area. As the Cold War developed missile and rocket technology grew more complex, increasingly expensive, and with the know-how dominated by the superpowers. Espionage aside, technical transfer tended to be restricted to spheres of influence of the two main superpowers. The United Kingdom and France were important secondary missile manufacturers; other nations produced no more than a handful of missiles for their own use. Many systems had distinctive infrastructure requirements and their remaining footprints document these Cold War alliances. Thor missile sites are found in England and equivalent sites were built at Vandenberg airbase and on the Marshall Islands. In Europe, American Nike and Hawk anti-aircraft missiles were supplied to allies and their remains are a tangible legacy of these treaties. It was the distinctive layout of Soviet missiles systems that alerted United States' intelligence officials to the presence of missiles on Cuba. Today, archaeologists using similar techniques, and declassified Cold War satellite imagery, are able study former deployment sites, including traces of temporary emplacements [39].

Surviving missile and rocket sites offer opportunities to tell the stories the rocket scientists and engineers who worked in these places and the processes of refining this pioneering technology. The surviving sites are monuments to the endeavours of the post war generation of rocket engineers and scientists, but they should also be seen as places to inspire new generations. The permanent missile deployment sites are important military monuments to wider narratives of changing Cold War strategies, the evolution of air defence systems and offensive weaponry.

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Protected Rocket and Missile Related Sites in England

Daws Hill, Buckinghamshire	USAF Computer centre, in part responsible for cruise missile mission planning – Listed Grade II*
Fort Halstead, Kent	Late 1930s experimental rocket assembly building – Listed Grade II
Greenham Common, Berkshire	Ground launched cruise missile shelters – Scheduled Wing Headquarters – Listed Grade II* Combat Support Building – Listed Grade II
Harrington, Northamptonshire	Thor missile site – Listed Grade II
North Luffenham, Rutland	Thor missile site – Listed Grade II*
Spadeadam, Cumbria, Rocket Establishment	British Oxygen Corporation site - Scheduled Component Test Area - Scheduled Engine Test Area - Scheduled Missile Test Area - Scheduled Abandoned silo excavations – Scheduled Blue Streak rocket F1 – Listed Grade II

The Needles, Isle of Wight	Saunders Roe test stands - Scheduled
Upper Heyford Oxfordshire	Hardened battle headquarters – including Rapier control room – Scheduled
Westcott, Buckinghamshire	German emplacements - Listed Grade II* Late 1940s P Site – Listed Grade II Blue Steel Test Site E – Listed Grade II K1 and K2 solid propellant test beds – Listed Grade II

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