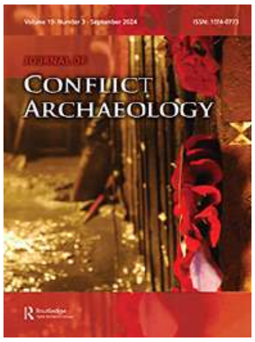

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Multi-disciplinary site investigations of WW2 allied aerial bombing decoy sites in North Staffordshire, UK

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ABSTRACT

In 1937, the British government implemented a strategy to strengthen UK air defences, constructing a network of decoy sites to mislead enemy aircraft from bombing Allied airfields, industrial centres and major cities. This paper reports on investigations of three relict aerial bombing decoy sites in Staffordshire, UK, deliberately built along German radio beam directions to divert enemy bombers from high priority industrial target sites. The three sites were in varying states of preservation, displaying control shelters with concrete bed generator rooms, headlamp platforms, relict electrical systems to simulated aeroplane runways, in situ blast walls and ceramic pipe blast expansion systems to protect personnel from bomb burst air concussions. Site-collected data included drone models, ground-based LiDAR, geophysical datasets and 360° camera imagery for digital site preservation. This study demonstrates these bombing decoy sites varied in construction and brings WW2 conflict history into the wider scientific community and public domain.

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WW2; decoy bombing sites; invasion; operation starfish; United Kingdom

Introduction

The 'Blitz' – the WW2 *Luftwaffe* bombing campaign of United Kingdom cities by Nazi Germany – remains a topic of great public interest (eg Baker 1978; Bright 2016; Calder 1969; Collier 1957; Doyle 2011a; Fitzgibbon 1970). Accordingly, a number of studies have examined both the destruction of the built environment and its reconstruction (e.Clapson and Larkham 2016; Moshenka 2009; Pohlad 2015), and the effects of the bombing on the civilian population, both physical and psychological (eg Beaven and Griffiths 1999; Beaven and Thoms 2013; Calder 1969, 1991; Grayzel 2012).

The bombing commenced with attacks on Royal Air Force (RAF) bases before London was targeted on 7 September 1940. Preparations for civilian response of 'passive defence' in the face of such bombing were enshrined in the UK Government's *Air Raid Precautions*

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Act of 1937 which, when it came into force on 1 January 1938, consolidated the relationship between the Government's plans for Civil Defence, and the responsibility of local government and the average citizen in providing for their own safety in wartime (O'Brien 1955; Woolven 1998, 2001). The main 'Blitz' took place over the period of 1940–41, though the attack of civilian targets re-emerged throughout the war, notably the Baedecker Raids of April–May 1942; the V-Weapons offensive of 1943–45; and the 'Little Blitz' of January–May 1944.

The effects of the bombing on towns and cities were documented even before the war had ended, most notably in the publication of many pamphlets that depicted the destruction by fire, often using emotive 'red skies' on their covers to emphasise the use of incendiaries, and the effects of conflagrations in cities such as London, Portsmouth, Manchester and others (see examples in Doyle and Evans 2007). This interest remains strong today, and this has fed into a growing archaeological, interest in the infrastructure and material culture of 'Blitzed Britain'. Such studies have considered, for example, efforts to protect the population through construction of air raid shelters (see Ainsworth et al. 2018; Thomas 2016), through to the material culture of 'the Blitz' (eg Doyle and Evans 2007; Moshenka 2008).

Much work in documenting the surviving militarised landscape of Britain was carried out in the Defence of Britain Project (Council for British Archaeology 2006). Initiated in 1995, this project created databases to inform responsible heritage agencies at both local and national level of surviving infrastructure with a view to the future preservation of surviving structures, and the databases exist in the Defence of Britain Archive (Council for British Archaeology 2006). This valuable approach has permitted the documentation of the remaining WW2 anti-invasion fortifications of Britain (eg see Dobinson, Lake, and Schofield 1997; Foot 2006; Schofield 2004), consisting of various concrete fortifications, defence lines and other positions (Barnes 2005; Thomas 2016), as well as the British Resistance underground bunkers and observation posts that would have been used during and after any Axis invasion (see Carr et al. 2020; Lampe 2007; Warwicker 2008). Despite this survey, in truth, archaeological projects associated with 20th century conflict have mainly concentrated on trenches, dug-outs, foxholes and other battle scars of front-line activity (see, for example, Banks 2014; Banks and Pollard 2014; Doyle 2017; Doyle, Barton, and Vandewalle 2005; Everett et al. 2006; Masters and Stichelbaut 2009); prisoner of war camps and escape activities (Doyle 2011b; Pringle, Doyle, and Babits 2007; Rees-Hughes et al. 2016); or the hospitals, airfields and other logistics of war (eg Capps Tunwell, Passmore, and Harrison 2015; Dobinson, Lake, and Schofield 1997; Passmore et al. 2017; Schofield 2001).

Nevertheless, since the beginning of the 21st Century, interest has been growing in an area of the military landscape of Britain that is rather more obscure, but which was to have a significant effect in reducing the tonnage of bombs released on Britain's industrial cities. As described by Dobinson (2000), this took the form of a series of decoys intended to deceive the *Luftwaffe* into dropping their bomb loads on relatively unimportant or uninhabited areas away from RAF bases and major towns and cities. Beginning in 1940 with efforts to deflect bombers away from RAF airfields, it soon expanded over the following three years to the protection of towns and cities, military installations, and major infrastructure points such as airfields or transport hubs. It is known that there were 797 sites deploying decoys, with some 1100 decoys – some of them dummy aircraft or military hardware, and estimates show that they were effective, with 5% of the German bombing effort displaced from their principal targets (Dobinson 2000).

The aim of this paper, therefore, is to describe the multi-technique site investigations used to analyse three Staffordshire-based bombing decoy sites, all in various states of preservation and most likely typical of the remaining bases in the UK. In this way, these case studies act as models that could be used in the application of specialist techniques in the consideration of the military landscape of the Second World War. The use of the non-invasive surveys employed here not only represents good practice but also demonstrates what can be done to locate and characterise such features and follows on from previous studies by the present team of authors in examining WW2 air raid shelters (Ainsworth et al. 2018) and Auxiliary Unit Bases (Carr et al. 2020) in the UK.

Operation Starfish: allied decoy bombing sites

Historical context

The threat of aerial attack to the British mainland became a reality in 1915 when Zeppelins dropped both explosive and incendiary bombs on the UK mainland, but it was the arrival of twin-engined Gotha bombers over London in the Spring of 1917 that heralded a new era of aerial assault on civilian targets (Grayzel 2012). The Italian military theorist Guilo Douhet is usually attributed in developing the concept of the attrition of civilian targets as an effective means of prosecuting war (Douhet 2017 [1921]), a concept that was put to the test in the Italian colonial campaign in Abyssinia in 1935 (Sbacchi 2005).

According to contemporary academic predictions based largely on Douhet's work, vast aerial armadas would destroy cities with high explosives and target the civilian populations with gas; casualties would be enormous, civil authorities would be overwhelmed; and cities would be razed to the ground (e.g. Cambridge Scientists Anti-War Group 1937; Haldane 1938). Such opinions gained credence following the devastating German-led bombing of Spanish cities during the Civil War of 1936–7, and the bombing of Britain was expected as an inevitability in the coming war. Planned countermeasures included the deployment of fighter aircraft, anti-aircraft guns and barrage balloons (Collier 1957), together with a programme of passive defence measures designed to protect the civilian population (O'Brien 1955). This was placed in sharp focus with the Munich Crisis of 1938, when preparations started in earnest (Woolven 1998, 2001). Extrapolation from these calculations led the Government to consider that 200,000 casualties were to be a likely result of a single week's bombing of Britain, of whom a third would perish (Dobinson 2000; O'Brien 1955).

Nevertheless, the defence of the UK had fallen to a low point in the post-war period. While in 1918 Britain could boast 286 anti-aircraft guns and 387 searchlights protecting its capital city, by 1920, this number had declined to zero (Collier 1957). Cognisant of this deficiency, in 1922, the Government set up a joint RAF/Army committee to consider future defence (Collier 1957). The resulting Steel-Bartholomew Committee identified three components of Britain's defensive strategy: 1, that the RAF should receive advance warning of attack in order to reach its fighting height; 2, that ground defences were essential to protect vulnerable points, particularly ports, and other transport nodes; and 3, that information on the movement of aircraft must be gained and disseminated quickly.

By the Munich Crisis of 1938, it was recognised that enemy bombing raids would likely be targeted at UK airfields to cripple the RAF and then major industrial cities to impair military production. The bombing of major cities was expected to reduce civilian morale, a phenomenon observed after the London Zeppelin raids in 1917 during WW1 which killed over 800 people (Grayzel 2012). Following the recommendations of the Steel-Bartholomew Committee, warning of the bombers approaching the coast was to be provided by both the Chain Home (CH) system (radar) constructed in 1935–37, and civilian spotters of the Observer Corps – necessary as radar could not detect enemy raiders once they passed over land (Collier 1957; Lowry 2004). By 1938, the Corps had established a network of posts in south and eastern England, later expanded to cover the rest of the country. From these often-isolated posts, observers could determine the altitude, direction and number of enemy raiders that could then be met by RAF fighters. Raiders were mostly preceded by the air raid sirens, intended to warn the public to head for shelters, and for the various Civil Defence (Air Raid Precautions, or ARP) organisations to ready themselves (Collier 1957; O'Brien 1955).

As part of the ground aerial defence of Britain, there was the deployment of tethered 'barrage balloons' under the control of RAF Balloon Command, established in 1938. These 65-feet-long silver 'gas bags' (designated Low Zone or LZ balloons) were used widely to protect vulnerable cities, ports and industry by forcing bombers to fly higher than their altitude of 5,000 feet (Collier 1957). The balloon barrage would reduce the accuracy of the bombing, as well as forcing the bombers to fly at an optimum altitude for anti-aircraft fire, as AA guns were less effective against lower flying aircraft. Here, searchlights, also deployed by the RAF, would comb the skies for enemy raiders. By the middle of 1940 there were 1,400 balloons, a third of them over the London area. Anti-Aircraft gun defences were to be gradually built-up throughout the early part of the war, with twelve divisions of the army's Anti-Aircraft Command (under General Frederick Pile) crewing the guns and searchlights (Lowry 2004; Pile 1949; War Office & Air Ministry 1943).

These approaches were intended to detect, deter and destroy enemy raiders in the air, while the complex passive defence infrastructure provided by the ARP services dealt with the aftermath of bombing incidents on the ground. But acknowledging that it was likely that enemy raiders would get through the defences, some other innovations were needed to mitigate their effects, thereby preserving both airfields and civilian infrastructure from complete destruction. One approach was the use of decoys, which might deceive a raider into believing they had reached their target, thereby unloading their bomb-load onto a low value target. This concept had been observed by officers of the Royal Naval Air Service (RNAS) at Immingham in Suffolk during WW1, who reported the tendency of Zeppelin raiders to unload their bombs at the first sight of light clusters on the ground. Though the Admiralty toyed with the idea of laying out decoy lights to replicate towns, signal lights to simulate railway infrastructure, or the use of flares to resemble fires, this was not taken further (Dobinson 2000). Though these ideas were revived – alongside the creation of dummy airfields – during the 1930s, again, they were not pursued until the dawn of war in 1939.

Colonel John Fisher Turner had supervised the expansion of RAF airfields from 1937 to 1939 and though he had technically retired in August 1939, due to his expertise on airfield design he returned to form a new department focusing on the use of bombing decoy sites for airfields no doubt inspired by the experience of WW1

(Dobinson 2000). By October of the same year, Turner had developed a plan for both day and night decoys to protect vulnerable airfields. As daytime visual aim targeting was the most common *Luftwaffe* bombing target identification at this point, a strategy was devised to create so-called 'K-site' decoys, replicas of simple airfields on grass, supplied with dummy aircraft that were obvious from 10,000 feet that were typical bomber flying height, but situated 5–6 miles away from the real airfield. To decoy night bombing raids, so-called 'Q sites' used paraffin flarepaths and electric lamps laid out to replicate airfield lighting and car headlights used to mimic aircraft taxiing (Crawley 2013; Dobinson 2000). Both airfield decoy types were completed by 1941.

The firebombing of Coventry on the night of 14th/15 November 1940 was to have serious consequences for British planning, as though dwarfed by later war Allied bombing campaigns, the scale of the casualties, including 554 dead and 865 seriously injured (Dobinson 2000; O'Brien 1955; Rasch 2006), was devastating. The threat to British manufacturing and the prosecution of the British war effort was also stark, with the German bombers being directed by radio beams (*X-Gerät*) to attack their targets that improved their accuracy. Importantly, though these beams would lead enemy bombers to significant locations, in poor weather conditions it would still be necessary for leading bombers to start fires in order to guide those that followed, the implication being that such fires were at the centre of the target to be attacked. This concept was reinforced by the fact that earlier in 1940 Q decoy sites at dummy airfields had often been targeted with incendiaries – confirmed by Luftwaffe prisoners, who indicated they were under orders to add further incendiaries to any fires they saw alight (Dobinson 2000). This led Turner to devise a modification, namely, the creation of 'Q Fire' or QF sites, equipped with the capability to recreate typical fires caused by bombing as a deception, and of 40 such sites created in July 1940, 12 of them were designated for aircraft factories (Dobinson 2000). With time, QF sites protecting RAF bases became increasingly more sophisticated, intended to mimic a range of fires in order to deceive more fully the enemy raiders.

With the threat to British cities and manufacturing sites demonstrated by the bombing of Coventry, from November 1940 Colonel Turner was ordered to expand the range of QF decoy sites to represent and therefore protect cities, at first concentrating on the industrial Midlands and using fuel oil to depict a growing conflagration. Turner called these sites 'Special Fire' or SF sites – soon given the code name Starfish – and from December 1940 new SF sites were added a rate of one a day until June 1941. By January, the list of civil sites had reached 43, covering most major towns and cities that could be targeted by the German *X-Gerät* direction system (Dobinson 2000). Alongside, radio countermeasures were designed to counter the German direction beam, and the SF decoy fires had already achieved success in February 1941, with those at Cardiff and Bristol drawing up to 175 high explosive bombs away from their intended targets (Collier 1957).

As subsequent bombing raids reduced in number at the end of the Blitz period, and following the German invasion of Russia, a third phase of decoy sites were constructed, so-called QL (Q sites with artificial lighting), with static 'leaky' lights replicating poorly blacked-out residential areas in open fields, and moving lights once again being used to simulate moving vehicles (Cowley, Standring, and Abicht 2010). At industrial sites, lighting was laid out in specific patterns to replicate factories in action. At their peak, there were 695 decoy sites around the UK with 209 of these being QL sites and with 171 being 'civil

QF' or SF sites (Figure 1). The rest of locations were mostly composed of naval decoy sites (Kolonko 2021).

By 1942 German bombing raids continued to decline as Allied bombing raids in Europe increased, and Colonel Turner's department focused on decoys related to the invasion of Europe in Operation Overlord (Stichelbaut 2009). In total there were 521 attacks on the night-time Q sites, of which 173 took place on QL (mimicking airfields) and QF (deploying fires) sites, deflecting around 900 tonnes of bombs. This contrasts with the 47 attacks on daytime K (using dummy aircraft and buildings) sites, which diverted 117 tonnes of bombs (Air Ministry 1950). Given the majority of raids were carried out at night, this is to be expected; nevertheless, those Q sites using fire were to be the most effective decoys in distracting the enemy raiders from their targets. A definition summary of the different decoy sites is provided in Table 1.

Bombing decoy site type and locations

SF or Starfish sites were constructed to deceive enemy bombers into offloading their bombs wherever fires were seen to be burning at ground level, the inference being that this was a target on fire. As discussed in detail by Dobinson (2000), the plan was to ensure that the sites were constructed along the path of the German radio beams that were the main method of navigation and direction finding during night-time operations. The network of sites was intended to provide protection for all major cities in mainland UK. Where there were large industrial cities, SF sites tended to be clustered close to the intended target, while others were in 'expansive layouts spreading over a vast area'

Figure 1. Bombing decoy SF (site fire) method, location unknown (Sullivan 2021). This probably represents a 'boiling oil' or 'coal drip' type fire.

Table 1. Definitions of the different bombing decoy site types, from Dobinson (2000).

Bombing Decoy Site Designation	Day/ Night Bombing Decoy	Description
K	Day	Bombing decoy airfield which included the use of dummy aircraft.
Q	Night	Lighting bombing decoy for airfields – achieved using paraffin flarepaths and electric lamps laid out to replicate airfield lighting, with moving car headlights used to mimic aircraft taxiing.
QF	Night	Small fire bombing decoy – which recreated typical fires caused by aerial bombing.
QL	Night	Lighting bombing decoy – used various light types to recreate 'poor-blackout' residential areas or working factories.
SF [Starfish]	Night	'Special fire' - civilian night QF sites which used fire bombing decoys (see Figure 1).

(Dobinson 2000, 90). Clusters or 'cordons' were common, but others were much more dispersed (Figure 2).

As described by Dobinson (2000) the decoy Starfish sites were separated in order to control the fires and prevent accidental conflagrations – as there was no active means of extinguishing the fires. Starfish fire types varied, and there were four main ones, intended to simulate different fire situations, and varying in complexity (Table 2). These types were arranged in groups in at Starfish sites, and they were controlled by a partially sunken (with a surface expression and covered by earth) or, later, above

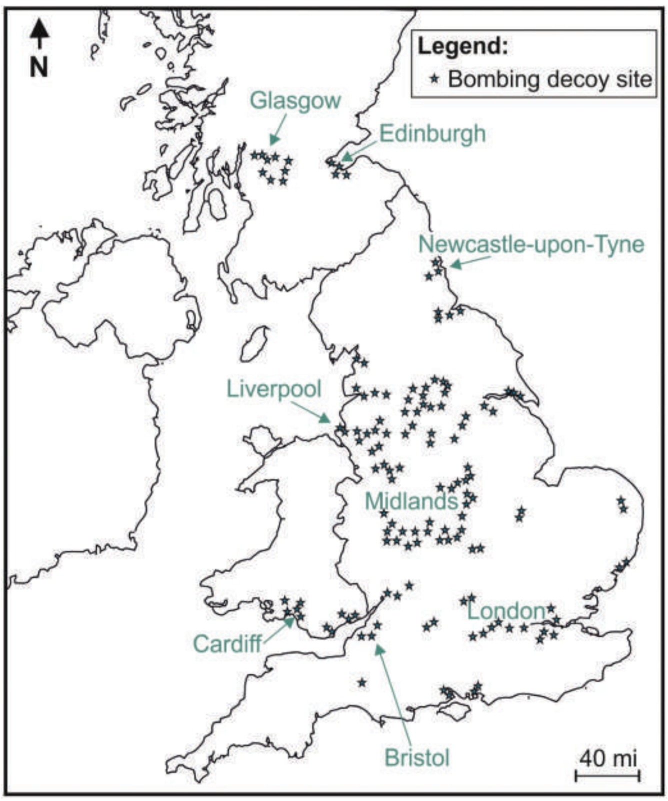

Figure 2. Approximate distribution of both civil and naval aerial bombing decoy sites, with likely named targets, June 1941. Redrawn from Dobinson (2000).

Table 2. 'Starfish' SF (fire types) aerial bombing decoy types, from Dobinson (2000).

Fire Type	Description
'Basket'	Small wooden crates lined with wire netting and filled with flammable materials. Used in groups, clusters or rows of 8, 16, or 24+ crates.
'Coal'/ 'Crib'	Longer burns than basket fires; single or double metal 20 ft brazier made of tubular piping, with a coal tray with electric igniters; it contained four hundredweight of firewood and three tons of coal; 'crib' fires used a wire-mesh container and flare cans.
'Boiling oil'	Heavy steel trough containing ten hundredweight of coal mixed with creosoted waste; fuel comprising diesel or gas oil and water was fed from tanks. Lit by igniters, the coat burned through a cord which opened the oil supply pipe; flushes of oil were vaporised and burnt with vigour; flushes of water created violent busts of fire, reaching 40 feet high. Fires burned on a supply of 480 gallons of oil and 200 gallons of water.
'Grid'	A framework of steel tubing with wire waste and metal turnings at the top, wicks and igniters below; paraffin was fed over this from a sprinkler released by the igniters burning through a release cord; fed by 180–200 gallon tank and producing a vivid yellow flame to bring variety.

ground, control shelter (Dobinson 2000). These shelters were the control centre, equipped with telephones and switchgear to ignite the fires, and are the subject of our study, as they are more likely to remain in the landscape today than the fire mechanisms themselves. As noted by Dobinson (107), they were mostly a 'rectangular cell walled with brick or concrete blocks obviously capped by reinforced concrete to withstand blast. Though early control sites were partially sunken, they were prone to flooding (in common with civilian air raid shelters), and therefore, above-ground brick shelters were used from 1941 (Figure 3).

Alternative text: Photograph showing flames and dark smoke billowing from a metal tray. Also shown are the elevated header tanks and connecting pipes that feed fuel to the metal tray. Onlookers can be seen within the image.

Alternative text: A schematic drawing of the United Kingdom with the location of aerial bombing decoy sites and the likely bombing targets marked.

Alternative text: Schematic diagrams for three different types of bombing decoy control shelter designs. Each vary in size and the contents found within. Each design has an entrance, alternative exit and is covered with earth.

Location of decoy bombing sites in North Staffordshire

The geology of North Staffordshire played a large role in the development of local industry. A rich abundance of clay, quick-burning coals, and ironstone meant that pottery, coal, and iron industries were well established in the area (Jenkins 1963). During the early years of WW2, Stoke-on-Trent was a strategic priority target for German bombing. Important targets included Wolstanton colliery, Shelton Steel and Iron Works, Meir aerodrome (Figure 4), the Michelin Tyre factory (bombed in January 1941), the railway goods yard, British Aluminium works and Radway Green munitions factory.

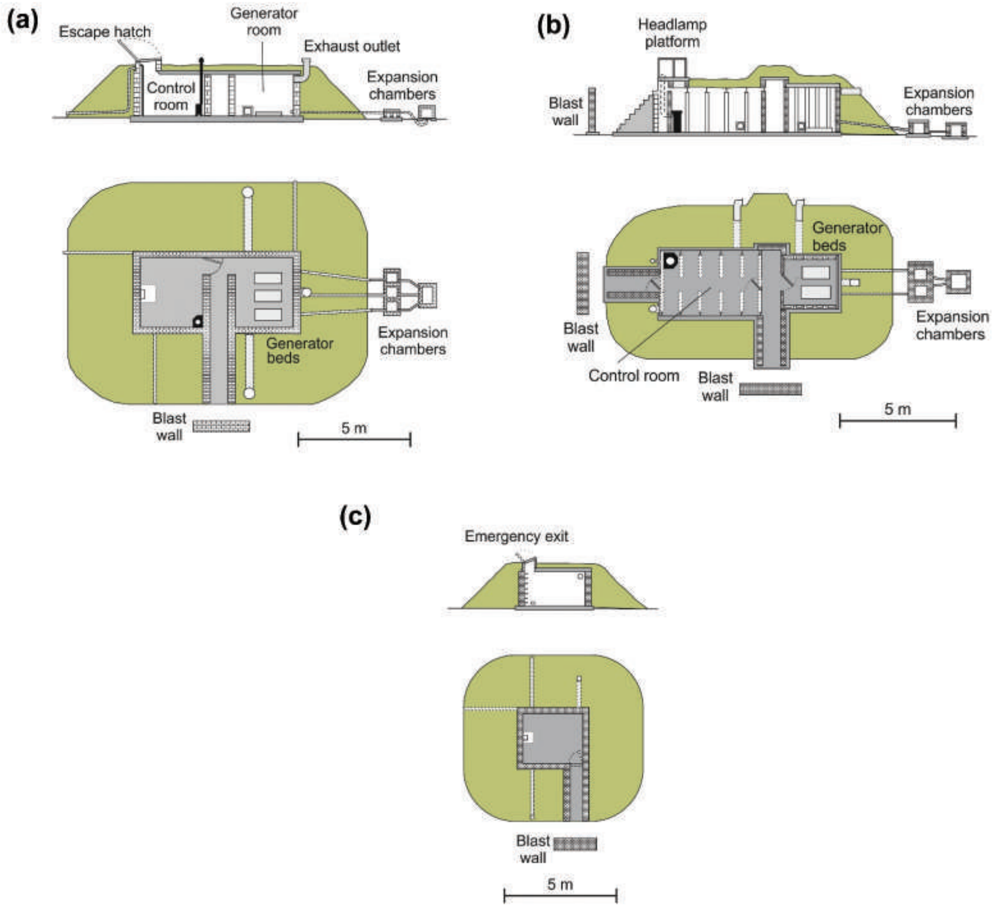

Figure 3. Schematic of aerial bombing decoy (table 1 for explanation) control shelter designs: (A) control shelter for QL site (air ministry drawing CTD 151/41), (B) control shelter for dram Q site (air ministry drawing CTD 367/41), and (C) starfish control shelter (air ministry drawing CTD 557/41). Images redrawn and adapted from Dobinson (2000).

The principal role of the SF decoy bombing sites in North Staffordshire was to divert enemy bombings from the city of Stoke-on-Trent through the use of controlled fires, intended to replicate areas previously bombed. The later incorporation of QL decoys at existing SF sites, served to mimic activities of local industry by simulating industrial factory lighting and train glows to mimic railway positions (Dobinson 2000).

Four aerial bombing decoy sites are known to have been constructed near to Stoke-on-Trent: 1) *Keele*, 2) *Beech*, 3) *Caverswall*, and 4) *Swynnerton* sites. The condition of the remains found at sites 1–3 is discussed in this paper; however, it was not possible to locate the exact position or remains of the Swynnerton site and so site investigations here were not undertaken. Figure 4 shows the location of the North Staffordshire bombing decoy sites in relation to some of the surrounding industry types present at that time that they were designed to protect.

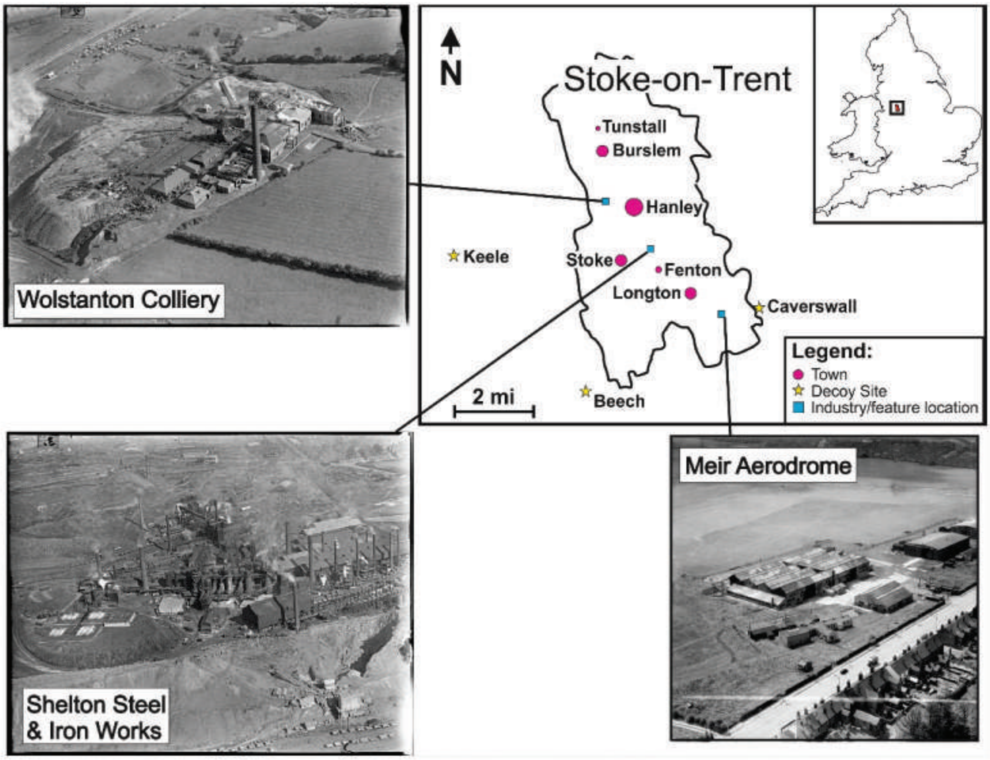

Figure 4. Contemporary map showing the location of the three WW2 aerial bombing decoy sites that were investigated in this study, together with some of the industries/feature locations with contemporary aerial images (source: historic England Archive. Reuse not permitted) that they were meant to protect.

Alternative text: Contemporary map showing the relative location of decoy sites compared to important industries/feature locations with contemporary aerial images of 'Wolstanton Colliery', 'Shelton Iron & Steel Works' and 'Meir Aerodrome'.

Site 1: Keele decoy site, stoke-on-trent, UK

The Keele decoy bombing site is situated in an elevated position in private land ~3 km south-south-east from Keele village and ~4 km south-west from the town of Newcastle-under-Lyme (Figure 4 for location). The site was built as a 'permanent Starfish' [SF] site in August 1941 and remained active until April 1943. This decoy site originally consisted of controlled fires, to replicate areas previously bombed and to encourage bombing away from the industrial sites of Stoke-on-Trent. By 1942, the site incorporated a QL decoy site, with simulated factory lighting and train glows, to mimic the nearby Wolstanton Colliery (see Figure 4). This site would have incorporated a number of different fire types that were controlled from the shelter that remains on site.

Study site reconnaissance discovered the only relict archaeological structure still present was a single-story control shelter (dimensions shown in Figure 4), brown ceramic pipes, electrical lamp bases, a blast wall in relatively good condition that was typical of QL shelter design, but with no evidence of an earth embankment (Figure 5). The control room interior showed the presence of large concrete bases required for the electrical generators and, interestingly, the remains of black-out curtains nailed onto the wooden door frames – an essential part of the black-out defences, equally applicable here – and pipe and brickwork debris (Figure 5). The concrete blast roof is still intact. See digital APPENDICES for interactive 360° images. Soil augers determined the Devensian clay soil type lying above the Upper Carboniferous Halesowen Formation sandstones and conglomerates' bedrock.

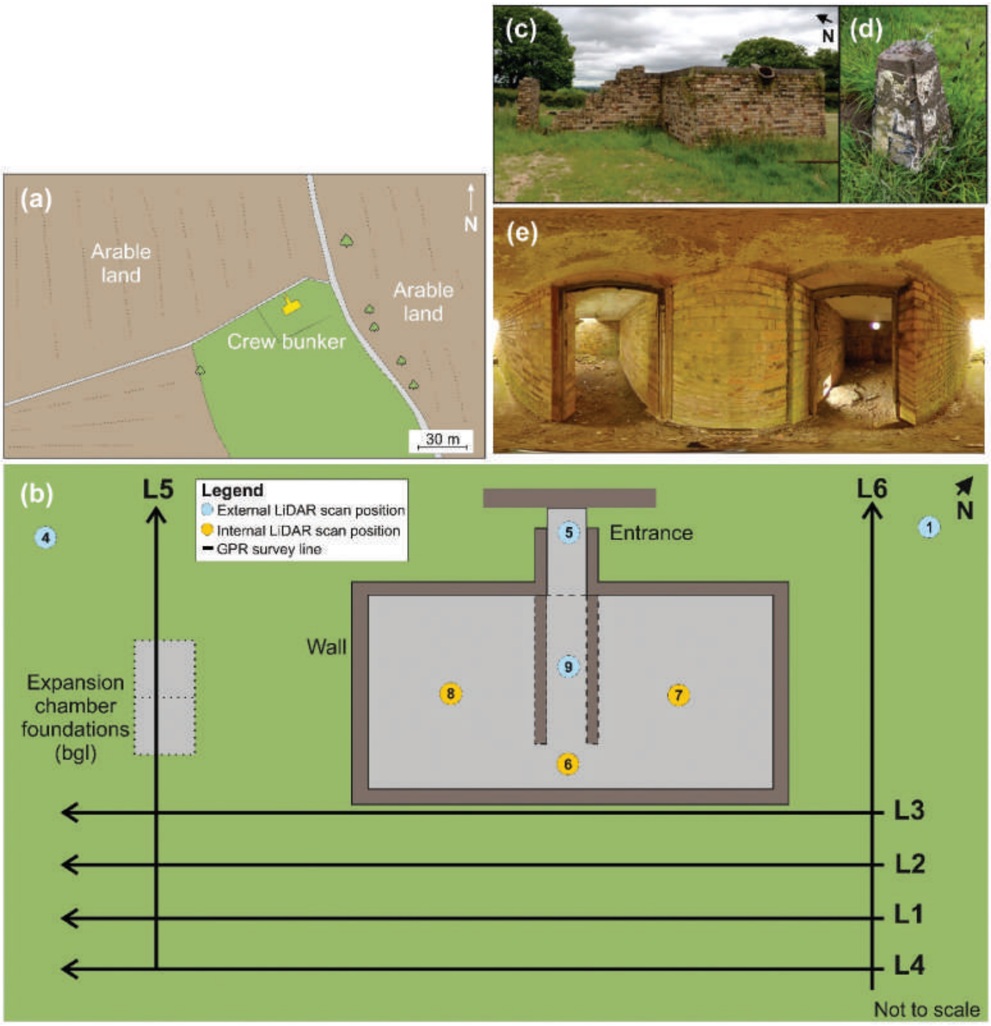

Figure 5. (a) Schematic site map of the keele decoy bombing site, Staffordshire, UK. (b) schematic of control crew shelter, blast expansion wall, electrical infrastructure and survey lines collected in this study; (c) site photograph of control crew shelter (view to the north) and (d) concrete base of electric lamp. (e) 360° image of shelter interior showing black-out curtain remains nailed on wooden door frames and shelter debris.

Alternative text: (a) A sketched map showing the general position of the decoy shelter in relation to surrounding features. (b) Schematic drawing of the shelter footprint with both GPR survey lines and LiDAR scan positions shown. (c) photograph of the exterior of the control shelter and (d) a concrete base of an electric lamp. (e) 360° photograph of the interior of the control shelter.

A UAV MavicPro™ drone was used at 10 m height onsite to collect 266 digital aerial images using Pix4D software before importing into Agisoft Metashape software to generate a 3D site model (Figure 6). Ground-based LiDAR surveys are commonly used to produce and digitally store spatially accurate site datasets (see Entwistle, McCaffrey, and Abrahams 2009; Johnson and Ouimet 2014).

A RIEGL™ VZ400i terrestrial LiDAR scanner was also used to collect 8 merged scan datasets taken both externally and internally, comprising ~11 million data points that were RGB coloured by a fish-eye lens camera mounted on top (Figure 6).

Alternative text: (a) Digital image of the control shelter, which was created from UAV aerial photographs. (b) An image of the control shelter which was generated from LiDAR scans.

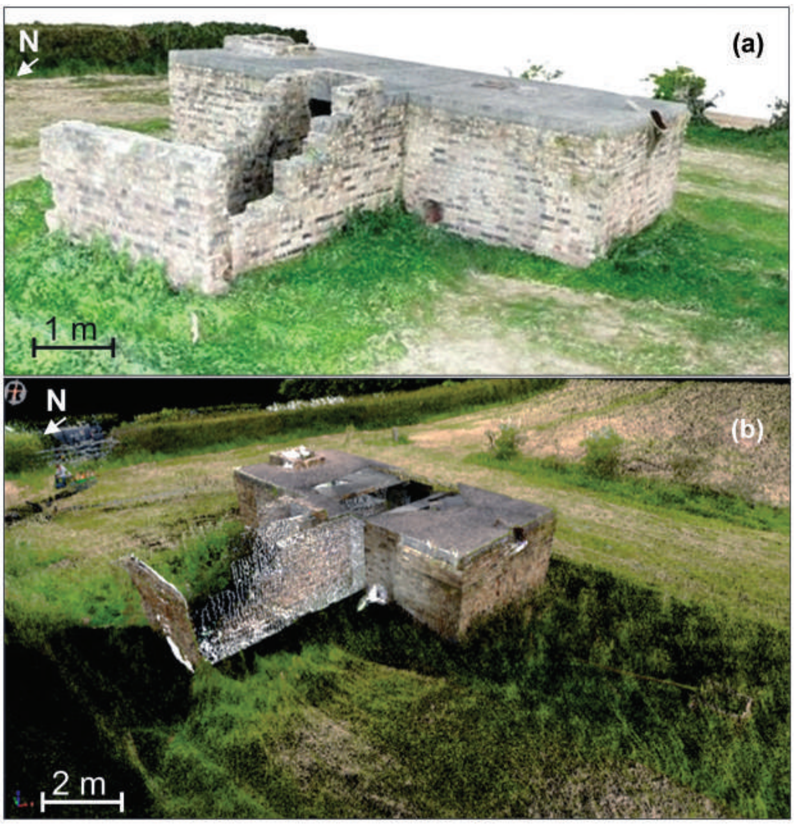

Figure 6. Keele decoy bombing site 3D digital models of the control crew shelter. Image (a) digital model generated from UAV drone aerial photographs; (b) digital site dataset generated from terrestrial LiDAR scans. See text for further details. Note that the still-intact thick concrete blast roof can be observed in both images.

For the GPR surveys that are commonly used in conflict archaeology to detect buried objects (see Dick et al. 2015; Sarris et al. 2013), a PulseEKKO™ Pro cart was used to collect six 2D 250 MHz profiles (Figure 5 for location) after trials using 500 MHz antenna found that the lower frequency produced better data. ReflexWIN™ v.8.5 software was then used to process the raw GPR images which included; first break arrival corrections to account for variable arrival times, manual gain filtering to boost deeper reflection events and time cuts to remove blank traces at profile bases (see Milsom & Eriksen 2011 for background).

GPR interpretations found positions of external electrical cabling and ceramic pipework connecting the control room to the below-ground expansion chambers, designed to protect the control room crew from nearby exploding bombs by dissipating the resulting bomb blast air pressure (Figure 7).

Alternative text: Image showing a GPR profile with arrows marking the positions of control shelter expansion chamber foundations (below ground level).

This site was ideal for surveying due to being in a relatively elevated position without any tree cover and no soil embankment, thus digital data collection was straightforward and produced excellent site digital models (see APPENDICES).

Site 2: Beech decoy site, stoke-on-trent, UK

The Beech decoy bombing site is situated in private deciduous dense mature woodland ~1 km from the village of Beech, Staffordshire (Figure 4 for location). This site was also built as a 'permanent Starfish' [SF] site in August 1941 and remained active until April 1943. In October 1942, a QL decoy was incorporated at the site with the added objective of protecting the local Shelton Iron and Steel Works in Stoke-on-Trent (see Figure 4).

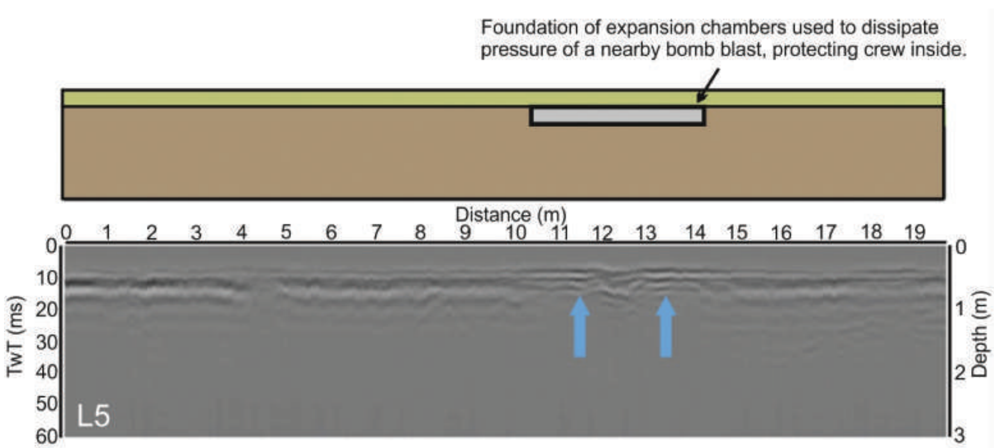

Figure 7. 250 MHz GPR 2D profile Line5, acquired to the south of the control room at the Keele site (see Figure 5 for location), and its interpretation of the expansion chamber foundations.

Following the desk study, site reconnaissance discovered the site had a very well-preserved control shelter, original blast wall and soil embankment (dimensions shown in Figure 4), in contrast to the Keele decoy bombing site, which was covered by post-war ground vegetation, bushes and surrounded by trees. The still-intact blast expansion chambers were also clearly visible and connected with well-preserved brown ceramic pipes. The intact shelter interior largely resembled the schematic layout in Figure 3. The soil type was identified as sandy/loam type lying above Early Triassic Chester Formation sandstone and conglomerate bedrock.

Dislodged buff-coloured bricks (dimensions: 230 × 110× 73 mm) from the control room (Figure 8) show the inscription 'PB Co. Ltd' - denoting 'Potteries Brick Company Limited' - a local marketing and sales company based in the Stoke-on-Trent area. Numerous brick-work manufacturers produced bricks under the PB Co. Ltd label and would add their own letter(s) to identify them as the manufacturer (e.g. 'A', 'AC', 'D', and 'K') – although it has not been possible to identity which wartime factory these markings refer to. PB Co. Ltd was listed by the Ministry of Supply (MoS) in 1943 (Kitching 2016), and it is believed that the additional 'V' stamp, located on the bottom right of the brick, stands for 'Victory' as it was produced for the Defence of Britain.

Due to the dense woodland, a UAV drone could not be used at this site to generate a site model. The RIEGL™ VZ400i terrestrial LiDAR scanner was used to collect 12 merged scans ~7 million data points that were RGB coloured by a fish-eye lens camera mounted on top (Figure 9).

Alternative text: (a) Sketch map showing the general position of the decoy shelter in relation to surrounding features. (b) Photograph showing partially buried main entrance to the shelter with an exposed blast wall. (c) Schematic drawing of the shelter footprint with both GPR survey lines and LiDAR scan positions shown. (d) Brick with the markings 'PB Co. Ltd' is also shown.

Alternative text: An image of the Beech control shelter which was generated from LiDAR scans.

For the GPR surveys, a PulseEKKO™ Pro cart was used to collect three 2D 250 MHz profiles (Figure 8 for location) and the same data processing steps as used in the Keele decoy study site data. GPR interpretations found relict archaeological features obscured by the many tree roots present onsite but did manage to characterise the buried control room roof (Figure 10), air vents and identified the positions of exterior ceramic pipework traced to the below-ground expansion chambers, similarly to the Keele decoy bombing site.

Alternative text: Image showing a GPR profile with an arrow and box marking the positions of an air void that is attributed to the internal rooms of the Beech control shelter.

Whilst the Beech control room shelter was relatively well preserved, the difficult nature of the site in dense woodland and undulating terrain made it difficult to collect usable digital site surveys, especially manual removal of above-ground vegetation in the models, causing significant data processing time to be spent.

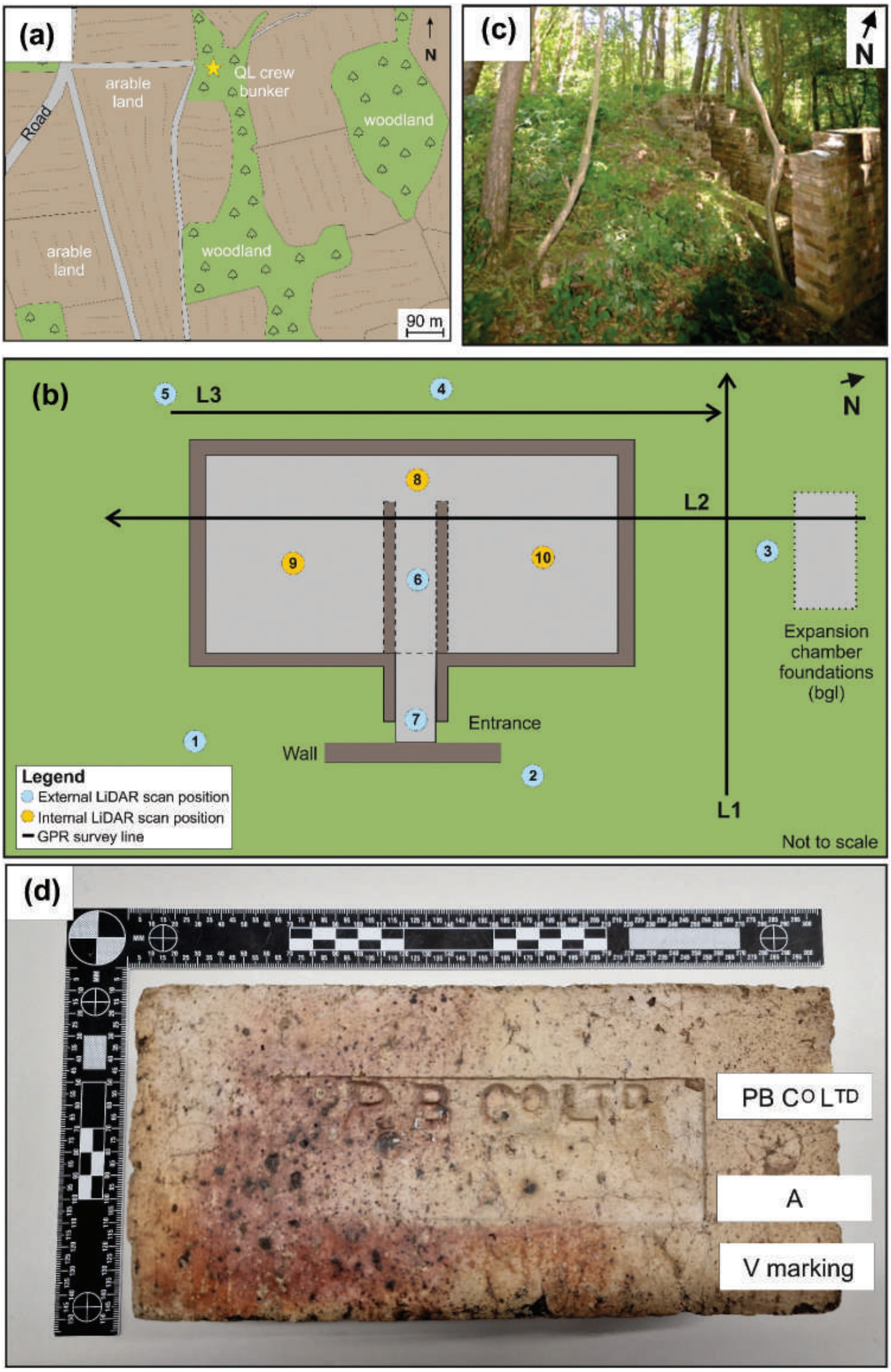

Figure 8. (a) schematic site map of the Beech site, Staffordshire, UK. (b) Modern photographs of control crew shelter exterior. (c) Schematic of control crew shelter, blast expansion wall, expansion chambers and survey lines collected in this study. (d). Wartime brick made by a local PB Co. Ltd. brickworks company – available via 360° walkthrough of shelter (see appendices).

Figure 9. The Beech bombing decoy site digital model of the control crew shelter and surrounding area produced from LiDAR terrestrial scans. See text for further details.

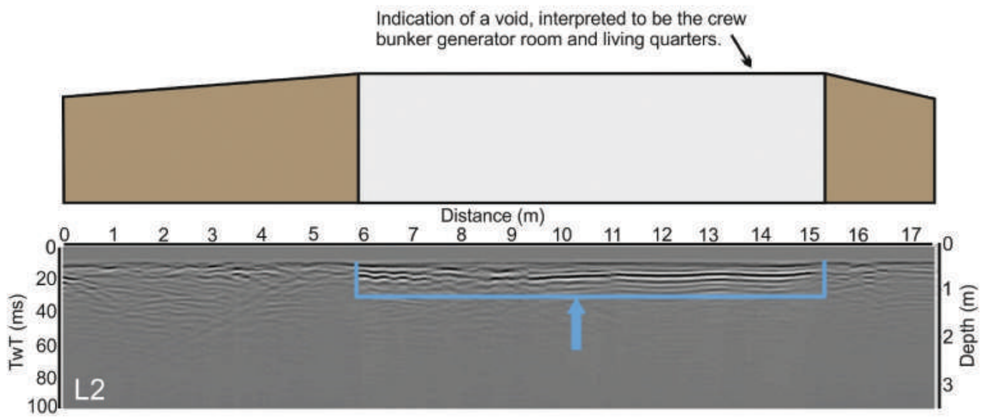

Figure 10. 250 MHz GPR 2D profile Line2, acquired to the south of the control room at the Beech site (see Figure 8 for location), and its interpretation of the expansion chambers.

Site 3: Caverswall decoy site, stoke-on-trent, UK

The Caverswall decoy bombing site is situated in an elevated position in public open grassland ~2.5 km north-west from the village of Caverswall and ~5 km east of Stoke-on-Trent (Figure 4 for location). This site was also built as a 'permanent Starfish' site in August 1941 to divert enemy bombing away from Stoke-on-Trent and remained active until April 1943. In October 1942, the site was incorporated into a QL decoy site to protect Stoke railway station and marshalling yard. This decoy site simulated marshalling yard lights, locomotive glows and factory lighting.

Post-war, the site was used as a marl pit, with the clay being used to locally to produce bricks. The site now is part of Park Hall Country Park. The only visible remains of the decoy bombing site are the concrete foundations and partial walls of the control crew shelter (dimensions shown in Figure 4), with evidence of an earth embankment at either end. The walls of the shelter, which stand at ~1.6 m, have been capped, possibly during partial demolition or as an attempt to make good/preserve the remaining structure. Survey lines were established across and parallel to the concrete foundation (Figure 11). The soil type was identified as a sandy loam lying above the Early Triassic Hulme Member conglomerate bedrock.

A UAV MavicPro™ drone was used at 10 m height onsite to collect 266 digital aerial images using Pix4D software before being imported into Agisoft Metashape software to generate a 3D site model (Figure 12). A RIEGL™ VZ400i terrestrial LiDAR scanner was also used to collect 8 merged scans ~9 million datapoint that were RGB coloured by a fish-eye lens camera mounted on top (Figure 12).

For the GPR surveys, a PulseEKKO™ Pro cart was used to collect three 2D 250 MHz profiles (Figure 11 for location) and the same data processing steps as used in the Keele decoy study site data. GPR interpretations found limited relict archaeological features but could trace the external blast wall foundations and the concrete base to have reinforced

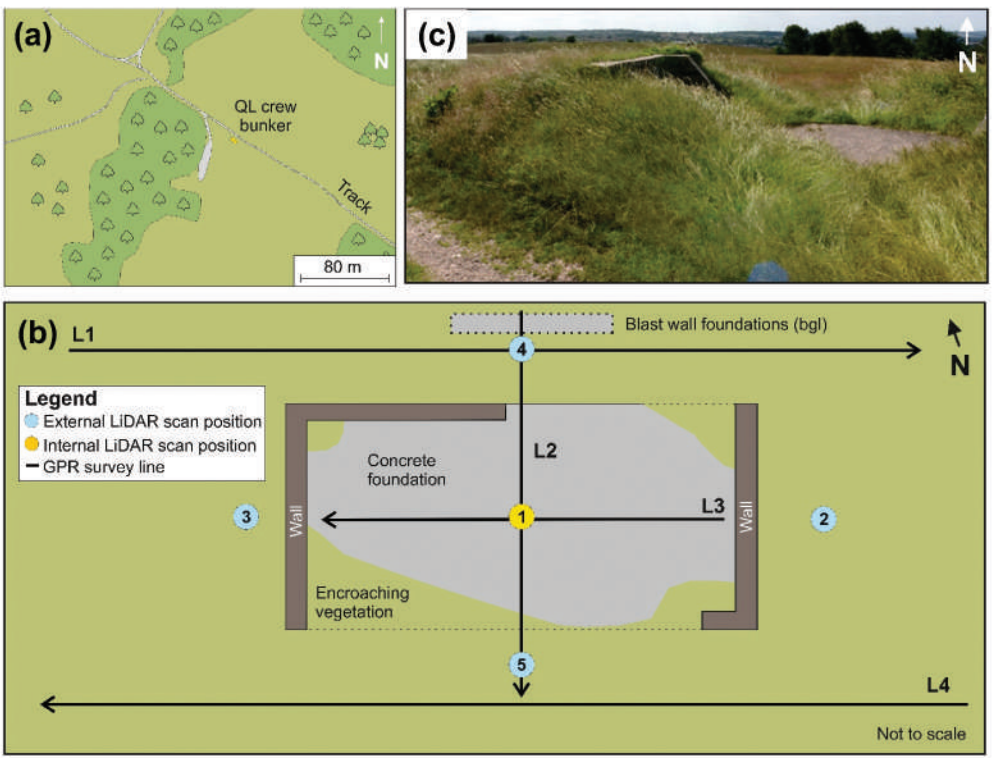

Figure 11. (a) schematic map of Caverswall decoy bombing site, Staffordshire, UK. (b): modern photograph of grass-covered control room wall and concrete base. (c) Schematic of remaining control crew shelter and survey lines collected in this study.

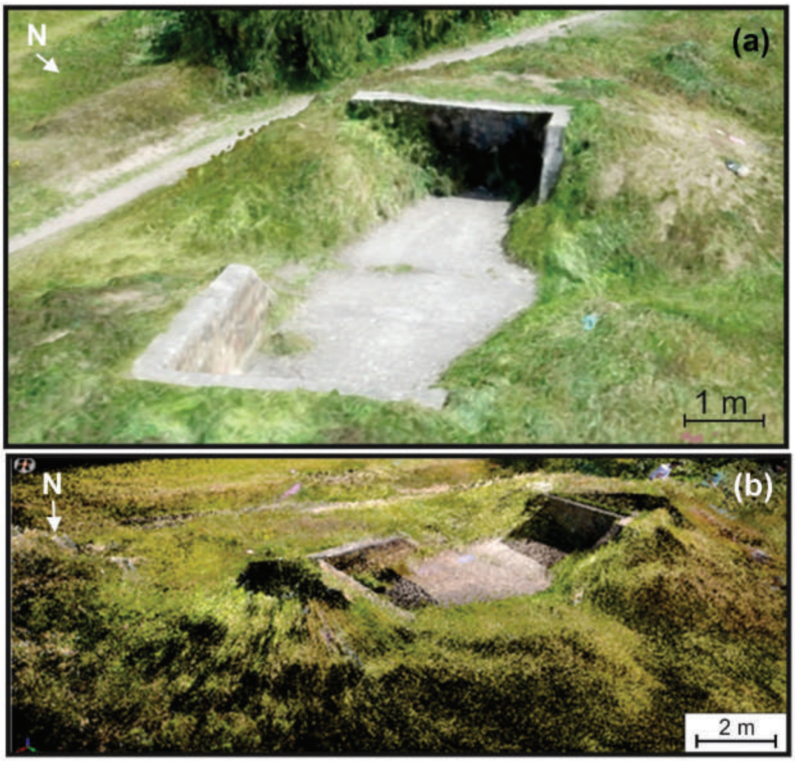

Figure 12. Caverswall decoy bombing site digital model of the control crew shelter and surrounding area produced from (a) UAV drone data and (b) LiDAR terrestrial scans. See text for further details.

metal bars to add base strength (Figure 13). GPR surveys were limited by site vegetation and obstacles east and west of bunker foundations (see Figure 11).

Alternative text: (a) Sketch map showing the general position of the Caverswall decoy shelter in relation to surrounding features. (c) Schematic drawing of the shelter footprint with both GPR survey lines and LiDAR scan positions shown. (b) Photograph of a mostly demolished shelter. Some of the concrete foundation and part of the east-facing wall can be seen.

Alternative text: (a) Digital image of Caverswall control shelter which was created from UAV aerial photographs. (b) Image of the control shelter generated from LiDAR scans.

Alternative text: Image showing a Caverswall GPR profile with two arrows marking 1) the position of the control shelter concrete foundations and 2) the possible foundations of the blast wall.

The limited relict archaeological remains at the Caverswall decoy site in an elevated position and lack of trees meant the 3D digital site models generated were relatively good.

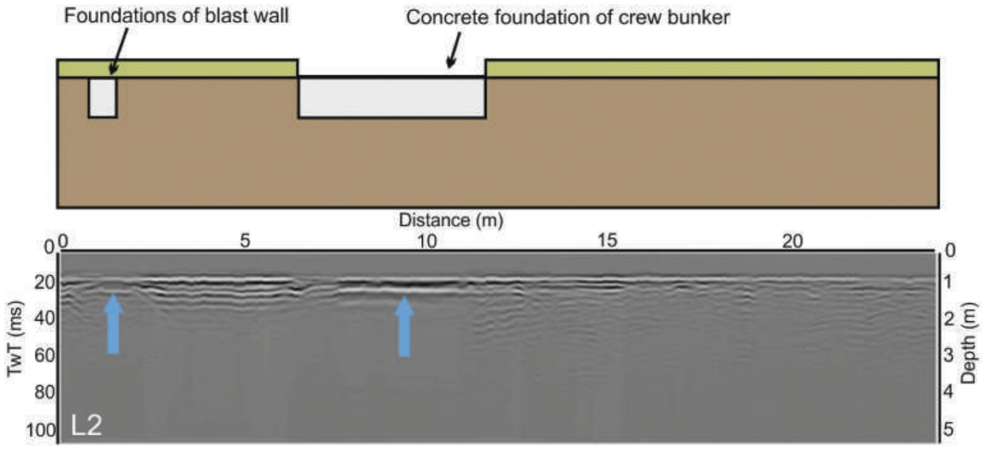

Figure 13. 250 MHz GPR 2D profile Line2, acquired to the north of the concrete base at the Caverswall site (see Figure 11 for location), and its interpretation of the blast wall foundation location.

Discussion

WW2 decoy bombing sites established in the United Kingdom were initially focused on protecting airfields so that the RAF could continue the air defence of Britain, but subsequently they were established to protect industrial sites and latterly cities as the Luftwaffe progressively changed their UK bombing strategies during the years of 1940 to 1943. 'Starfish' was an approach that undermined the German dependence on radio beam location, relying on the principle that German bombers would usually add additional bombs to a growing conflagration on their flightpath, just as had happened to the city of Coventry in November 1940. That this approach was effective is evidenced by a number of accounts that showed that decoy sites were very much the recipients of German bombing attacks (Collier 1957).

This study is the first detailed examination of the surviving remains of permanent 'Starfish' or SF decoy sites that were intended, through the use of controlled fires, to deceive the German *Luftwaffe* into dropping their bombloads on to relatively uninhabited areas away from their intended targets. This type of WW2 air defence was effective but largely overlooked relative to the activities of the RAF and of anti-aircraft artillery and searchlight batteries, and this study builds on the pioneering work of Colin Dobinson (Dobinson 2000) in bringing the technique into the public eye.

'Starfish' decoy sites comprised a range of structures that delivered different fire types that were intended to deceive the enemy bombers into believing they were observing the burning of factories, towns and cities below them. For the most part, these structures were built from scaffolding and other steel pipe structures, with oil tanks, steel pans and wire mesh being typical. These were by design temporary and are unlikely to remain at surface in remaining sites. Nevertheless, each site had a permanent structure designed to house and protect essential control and communications equipment, as well as the personnel who were in charge of the site and its operation. Typically, these buildings remain in the landscape, typically in a variety of states, and this study has used modern techniques to characterise and survey three such sites that remain in and around the city of Stoke on Trent in the Midlands (see Figure 4), a likely target for German bombers during

WW2. It is thought that around twenty bombing attacks took place over the Stoke-on-Trent area during the early years of the war, although documented evidence is difficult to ascertain for this area.

This paper evidences that non-invasive digital surface and near-surface surveys can rapidly detect, characterise and digitally capture these relict archaeological sites, which other researchers have used on such WW2 sites (eg Ainsworth et al. 2018; Carr et al. 2020; Everett et al. 2006; Gaffney et al. 2004). Modern surface surveys use a combination of UAV drones and ground-based digital data hardware to digitally record and document such structures, allowing both their digital preservation and ability to be interrogated at later dates and to be disseminated to a wider audience that could visit such sites, often situated on private land. These can also be interactively viewed in three dimensions and are provided in the paper's APPENDICES. Near-surface geophysical surveys, whilst not used extensively in this study as others have (eg Everett et al. 2006; Gaffney et al. 2004), still could allow tracing of near-surface buried structures to gain a wider understanding of what such structures were designed for.

The discovery of the expansion chamber foundations at the Keele and Beech decoy sites evidences how, even in those desperate times, site designers were still aware of how dangerous these decoy sites were for the personnel manning them, and tried to give them a better chance of surviving concussions from nearby bomb blasts, which is what they were hoping for.

Conclusions

This paper presents results of non-invasive geoscientific surveys of WW2 bombing decoy relict archaeological 'Starfish' sites in Staffordshire in the UK. Whilst in a similar geographic area, they are in various states of preservation, thus providing a means of determining the likely relict archaeology of these sites expected elsewhere in the UK. Most brick control rooms were still present in the QL decoy sites, with reinforced concrete bases needed for the electrical generators powering the artificial lighting to represent airfields, industrial sites and railways. Interestingly, external blast walls and the infrastructure of expansion chambers evidenced the defensive structural design of the QL decoy bombing sites, to allow the crew manning the stations the best chance to survive the air concussions from nearby bomb blasts that they were hoping for. Evidence of black-out curtains also remained on internal wooden door frames.

Whilst this study is limited to Staffordshire, further work should survey other UK Starfish bombing decoy sites, ideally surveying and digitally recording examples of all the different bombing decoy types created which have not been surveyed in this study, to give a much broader spectrum of the likely preservation of these hitherto forgotten WW2 decoy sites.

This study has shown how modern non-invasive surveying techniques can detect and characterise such relict archaeological decoy bombing sites and provide new knowledge of this desperate time during WW2 for the UK.

Geolocation information

Two of these sites (Keele and Beech) are on private land, and as such, should not be accessed without permission from the landowners.

The Keele site has the following co-ordinates: 52°58′54″ N 2°16′11″ W. The Beech site has the following co-ordinates: 52°56′04″ N 2°13′22″ W. The Caverswall site has the following co-ordinates: 52°59′48″ N 2°06′12″ W.

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References

Ainsworth, J. T., J. K. Pringle, P. Doyle, M. Stringfellow, D. Roberts, I. G. Stimpson, K. D. Wisniewski, and J. Goodwin. 2018. "Geophysical Investigations of WWII Air-Raid Shelters in the UK." *Journal of Conflict Archaeology* 13 (3): 167–197. https://doi.org/10.1080/15740773.2018.1583472.

Air Ministry. 1950. *Decoy and Deception*. London: AIR 41/3, The National Archives.

Baker, J. 1978. *Enterprise versus Bureaucracy: The Development of Structural Air-Raid Precautions During the 2nd World War*. London: Pergammon Press.

Banks, I. 2014. "Digging in the Dark: The Underground War on the Western Front in World War I." *Journal of Conflict Archaeology* 9 (3): 156–176. https://doi.org/10.1179/1574077314Z.00000000038.

Banks, I., and T. Pollard. 2014. "Beyond Recall: Searching for the Remains of a British Secret Weapon of World War I." *Journal of Conflict Archaeology* 9 (3): 119–155. https://doi.org/10.1179/1574077314Z.00000000037.

Barnes, R. 2005. "Russell W. Barnes' Guide to 20th Century Defence Architecture in Cumbria, England." Accessed February 14, 2018. http://www.users.globalnet.co.uk/~rwbarnes/index.htm.

Beaven, B., and J. Griffiths. 1999. "The Blitz, Civilian Morale and the City: Mass-Observation and Working-Class Culture in Britain, 1940–41." *Urban History* 26 (1): 71–88. https://doi.org/10.1017/S0963926899000152.

Beaven, B., and D. Thoms. 2013. "The Blitz and Civilian Morale in Three Northern Cities, 1940–1942." *Northern History* 32 (1): 195–203. https://doi.org/10.1179/007817296790175191.

Bright, N. 2016. *Southwark in the Blitz*, 128. Stroud: Amberley.

Calder, A. 1969. *The People's War*. London: Jonathan Cape.

Calder, A. 1991. *The Myth of the Blitz*. London: Jonathan Cape.

Cambridge Scientists Anti-War Group. 1937. *The Protection of the Public from Aerial Attack*, 127. London: Left Book Club (Victor Gollancz).

Capps Tunwell, D., D. Passmore, and S. Harrison. 2015. "Landscape Archaeology of World War Two German Logistics Depots in the Forêt Domaniale des Andaines, Normandy, France." *Historical Archaeology* 19 (2): 233–261. https://doi.org/10.1007/s10761-015-0287-4.

Carr, S., J. K. Pringle, P. Doyle, K. D. Wisniewski, and I. G. Stimpson. 2020. "'Scallywag Bunkers': Geophysical Investigations of WW2 Auxiliary Unit Operational Bases (OBs) in the UK." *Journal of Conflict Archaeology* 15 (1): 4–31. https://doi.org/10.1080/15740773.2020.1822102.

Clapson, M., and P. J. Larkham, eds. 2016. *The Blitz and Its Legacy. Wartime Destruction to Post-War Reconstruction*, 220. London: Routledge.

Collier, B. 1957. *The Defence of the United Kingdom*, 588. London: HMSO.

Council for British Archaeology. 2006. "Defence of Britain Archive." Accessed December 30, 2023. https://archaeologydataservice.ac.uk/archives/view/dob/overview.cfm. doi: 10.5284/1000327.

Cowley, D., R. Standring, and M. Abicht. 2010. *Landscapes Through the Lens*. 1st ed. Oxford: Oxbow Books.

Crawley, G. 2013. "Proving Grounds: Live Fire, Starfish and Incendiaries." *Performance Research* 18 (1): 105–112. https://doi.org/10.1080/13528165.2013.789256.

Dick, H. C., J. K. Pringle, B. Sloane, J. Carver, K. D. Wisniewski, A. Haffenden, S. Porter, D. Roberts, and N. J. Cassidy. 2015. "Detection and Characterisation of Black Death Burials by Multi-Proxy Geophysical Methods." *Journal of Archaeological Science* 59: 132-141. 10.1016/j.jas.2015.04.010.

Dobinson, C. 2000. *Fields of Deception*, 320. London: Methuen Publishing Ltd.

Dobinson, C., J. Lake, and A. Schofield. 1997. “Monuments of War: Defining England’s 20th-Century Defence Heritage.” *Antiquity* 71:288–299. https://doi.org/10.1017/S0003598X0008491X.
Doyle, P. 2011a. *The Blitz*, 56. Oxford: Shire.
Doyle, P. 2011b. “Geology of World War II Allied Prisoner of War Escape Tunnels.” *International Handbook of Military Geography* 2:144–156.
Doyle, P. 2017. *Disputed Earth. Military Geology and Trench Warfare on the Western Front, 1914–1918*. London: Uniform Press.
Doyle, P., P. Barton, and J. Vandewalle. 2005. “Archaeology of a Great War Dugout: Beecham Farm, Passchendaele, Belgium.” *Journal of Conflict Archaeology* 1 (1): 45–66. https://doi.org/10.1163/157407705774928908.
Doyle, P., and P. Evans. 2007. *The Home Front. British Wartime Memorabilia, 1939-45*, 208. Marlborough: Crowood Press.
Entwistle, J. A., K. J. W. McCaffrey, and P. W. Abrahams. 2009. “Three-Dimensional (3D) Visualisation: The Application of Terrestrial Laser Scanning in the Investigation of Historical Scottish Farming Townships.” *Journal of Archaeological Science* 36 (3): 860–866. https://doi.org/10.1016/j.jas.2008.11.018.
Everett, M. E., C. J. Pierce, R. R. Warden, D. R. Dickson, R. A. Butt, J. C. Bradford, and J. C. Bradford. 2006. “Geophysical Investigation of the June 6th 1944 D-Day Invasion Site at Pointe du Hoc, Normandy, France.” *Near Surface Geophysics* 4 (5): 289–304. https://doi.org/10.3997/1873-0604.2005052.
Fitzgibbon, C. 1970. *The Blitz*, 272. London: Macdonald.
Foot, W. 2006. Beaches, Fields, Streets, and Hills … the Anti-Invasion Landscapes of Britain. *CBA Research Report 144*. Council for British Archaeology, York, 658.
Gaffney, C., J. Gater, T. Saunders, and J. Adcock. 2004. “D-Day: Geophysical Investigation of a World War II German Site in Normandy, France.” *Archaeological Prospection* 11 (2): 121–128. https://doi.org/10.1002/arp.233.
Grayzel, S. 2012. *At Home and Under Fire: Air Raids and Culture in Britain from the Great War to the Blitz*. 3rd ed. Cambridge: Cambridge University Press.
Haldane, J. B. S. 1938. *A.R.P*, 296. London: Victor Gollancz.
Jenkins, J. G. 1963. *Stoke-On-Trent: Federation and After*. Vol. VIII. London: Victoria County History (VCH) Staffordshire.
Johnson, K. C., and W. B. Ouimet. 2014. “Rediscovering the Lost Archaeological Landscape of Southern New England Using Airborne Light Detection and Ranging (LiDAR).” *Journal of Archaeological Science* 43:9–20. https://doi.org/10.1016/j.jas.2013.12.004.
Johnson K M and Ouimet W B. (2014). Rediscovering the lost archaeological landscape of southern New England using airborne light detection and ranging (LiDAR). Journal of Archaeological Science, 43: 9–20. 10.1016/j.jas.2013.12.004
Kitching, D. 2016. *British Bricks*. Gloucestershire: Amberley Publishing.
Kolonko, C. 2021. “Decoys and Rubble - Taking Another Look at the Wartime coast’.” *Merseyside Archaeological Society Newsletter 1/2021* 4.
Lampe, D. 2007. *The Last Ditch: Britain’s Resistance Plans Against the Nazis*. Barnsley: Greenhill Books.
Lowry, B. 2004. *British Home Defences 1940-45*, 64. Oxford: Osprey.
Masters, P., and B. Stichelbaut. 2009. “From the Air to Beneath the Soil – Revealing and Mapping Great War Trenches at Ploegsteert (Comines-Warneton), Belgium.” *Archaeological Prospection* 16 (4): 279–285. https://doi.org/10.1002/arp.357.
Moshenka, G. 2008. “A Hard Rain. Children’s Shrapnel Collections in the Second World War.” *Journal of Material Culture* 13 (1): 107–125. https://doi.org/10.1177/1359183507086221.
Moshenka, G. 2009. “Resonant Materiality and Violent Remembering: Archaeology, Memory and Bombing.” *International Journal of Heritage Studies* 15 (1): 44–56. https://doi.org/10.1080/13527250902746062.
O’Brien, T. H. 1955. *Civil Defence*, 729. London: HMSO.
Passmore, D. G., D. Capps-Tunwell, M. Reinders, and S. Harrison. 2017. “Towards an Archaeology and Geography of Second World War German Munitions Storage Sites in North-West Europe.” *Journal of Conflict Archaeology* 12 (1): 46–71. https://doi.org/10.1080/15740773.2017.1426535.

Pile, F. 1949. *Ack-Ack: Britain's Defence Against Air Attack During the Second World War*. London: Harrap.
Pohlad, M. B. 2015. "The Appreciation of Ruins in Blitz-Era London." *The London Journal* 30 (2): 1–24. https://doi.org/10.1179/ldn.2010.30.2.1.
Pringle, J. K., P. Doyle, and L. E. Babits. 2007. "Multidisciplinary Investigations at Stalag Luft III Allied Prisoner-Of-War Camp: The Site of the 1944 "Great Escape," Zagan, Western Poland." *Geoarchaeology* 22 (7): 729–746. https://doi.org/10.1002/gea.20184.
Rasch, W. 2006. "'It Began with Coventry': On Expanding the Debate Over the Bombing War." In *Bombs Away! - Representing the Air War over Europe and Japan* (Amsterdam: Brill), 395–404 doi: 10.1163/9789401201919_025.
Rees-Hughes, L., J. K. Pringle, N. Russill, K. Wisniewski, and P. Doyle. 2016. "Multidisciplinary Investigations at P.O.W. Camp 198, Bridgend, S. Wales: Site of a Mass Escape in March 1945." *Journal of Conflict Archaeology* 11 (2–3): 166–191. https://doi.org/10.1080/15740773.2017.1357900.
Sarris, A., N. Papadopoulos, A. Agapiou, M. C. Salvi, D. G. Hadjimitsis, W. A. Parkinson, W. R. Yerkes, A. Gyucha, and R. P. Duffy. 2013. "Integration of Geophysical Surveys, Ground Hyperspectral Measurements, Aerial and Satellite Imagery for Archaeological Prospection of Prehistoric Sites: The Case Study of Vésztő-Mágor Tell, Hungary." *Journal of Archaeological Science* 40 (3): 1454–1470. https://doi.org/10.1016/j.jas.2012.11.001.
Sbacchi, A. 2005. "Poison Gas and Atrocities in the Italo-Ethiopian War (1935–1936)." In *Italian Colonialism. Italian and Italian American Studies*, edited by R. Ben-Ghiat and M. Fuller. New York: Palgrave Macmillan. https://doi.org/10.1007/978-1-4039-8158-5_5.
Schofield, J. 2001. "D-Day Sites in England: An Assessment." *Antiquity* 75 (287): 77–83. https://doi.org/10.1017/S0003598X00052753.
Schofield, J. 2004. *Modern Military Matters. Studying and Managing the Twentieth-Century Defence Heritage in Britain: A Discussion Document*, 62. York: Council for British Archaeology.
Stichelbaut, B. 2009. *Images of Conflict*, 260–275. Newcastle upon Tyne [England]: Cambridge Scholars Pub.
Sullivan, S. 2021. "Decoy QL Sites." *Blighty-At-War*. Accessed September 17, 2021. https://www.blighty-at-war.net/decoy-ql-sites.html .
Thomas, R. J. C. 2016. "Civil Defence: From the First World War to the Cold War." *Historic England*. Last accessed May11, 2018. www.historicengland.org.uk/listing/selection-criteria/listing-selection/ihas-buildings/ .
War Office & Air Ministry. 1943. *Roof Over Britain: The Official Story of Britain's Anti-Aircraft Defences 1939-1942*. London: HMSO.
Warwicker, J. 2008. *Churchill's Underground Army: A History of the Auxiliary Units in World War II*. Barnsley: Frontline Books.
Woolven, R. 1998. "Munich, London and ARP." *The RUSI Journal* 143 (5): 54–58. https://doi.org/10.1080/03071849808446311.
Woolven, R. 2001. *Civil Defence in London 1939-1945*. Unpublished PhD Thesis, London, King's College. https://kclpure.kcl.ac.uk/ws/portalfiles/portal/2927729/DX225968.pdf.

Appendices

360° walkthrough of the three investigated decoy sites can be found via the following link: https://www.thinglink.com/card/1821938323082445477.