A ‘Baby GDA’: Norwich’s Airspace during the Second World War

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Throughout the Second World War, the Luftwaffe attacked Norwich on various occasions. The impact this had on the city was recorded visually on the ‘Norwich Bomb Map’. This cartographic depiction, however, only records a single ‘horizontal’ component of the aerial ‘battlescape’. In reality, the aerial battlefield comprised a combination of Norwich’s air defences and the flightpaths of the Luftwaffe bombers, which existed in three-dimensional space. As other scholars have developed methodologies for reconstructing anti-aircraft ‘fire domes’, this article will combine these concepts with a new approach that reconstructs historic flightpaths to give a three-dimensional overview of Norwich’s ‘Gun Defended Area’. By examining all components of Norwich’s airspace, this article will demonstrate the importance of considering the vertical component of a battlescape.

Keywords: Air defence; Luftwaffe; Norwich; airspace; bombscape; firedome; aerial battlescape

Introduction

For many cities in the UK during the Second World War, a visual record of bomb impact locations was recorded cartographically on a ‘Bomb Map’. These represent a landscape record of aerial bombing, or a ‘bombscape’ (Figure 1), but they are not ‘neutral tools’: maps ‘actually represent “reality” selectively and are anything but objective’ (Johnson 2006, 85). It is essential, therefore, when working with maps to question and understand them in context (Fleming 2007, 93). This is especially important in analysing aspects of military aviation and the landscape of aerial bombing, when it is vital to remember that cartographic representations only depict the horizontal component of the battlescape.

Examining the world from a bird’s eye viewpoint has long dominated the work of geographers (Graham and Hewitt 2012, 72). This approach ignores the ‘vertical dimension and tends to look across rather than to cut through the landscape’ (Weizman 2002, 3, cited Graham 2004, 12). There has been, however, a growing awareness amongst scholars of the importance of incorporating a vertical dimension into the analysis of landscapes (Adey 2010; Graham 2004; Williams 2013; Baghel and Nüsser 2015; Elden 2013; Weizman 2017; Harris 2015). It is not easy to depict airspaces cartographically (Crampton 2010, 96), but developments in aerial mobility, geographies

of civil air travel and the geopolitics of airpower, have led to a more critical view of vertical space (Williams 2013, 254).

The study of three-dimensional landscapes (von Schwerin *et al*. 2013; Campana *et al*. 2012; Dell'Unto *et al*. 2016; Stewart 2019) and air warfare (Cocroft and Wilson 2006; Whorton 2002; Richardson 2008) are not new areas of research within the field of archaeology. To date, aviation archaeologists have generally focused their research on the Second World War (Tunwell, Passmore and Harrison 2016, 312), with work conducted on aircraft crashes (Holyoak 2002; Fuller and Quigg 2011), airfields (Lake 2002; Moshenska 2012), and air defence (Dobinson 2001; Dobinson, Lake and Schofield 1997). Limited work, however, has been undertaken on the archaeology of aerial bombing (Tunwell, Passmore and Harrison 2016, 312). Those studies that have been conducted only focus on the landscape dimension (Tunwell, Passmore and Harrison 2015, 234).

The work of Dorothy Sprague, Dirk Spennemann and Craig Poynter (Sprague 2018; Spennemann 2017; Spennemann and Poynter 2019) combines three-dimensional analysis with aviation history. Sprague plotted the airspace of predefined approach zones to predict B-29 Superfortress crash sites in the Pacific Theatre of the Second World War. Working in the same geographical region, Spennemann and Poynter developed methodologies for reconstructing the 'fire domes' of Japanese anti-aircraft guns. The aim of this article is to combine the approaches devised by Sprague, Spennemann and Poynter, to develop the concepts of three-dimensional airspace analysis further, and to apply them to the city of Norwich (UK) during the Second World War. The author will present a new approach to plot the unpredictable flightpath of aircraft during a bomb run. By reconstructing the city's airspace during the Second World War, this article will demonstrate the potential of using archival sources to reconstruct three-dimensional aerial battlescapes.

Over the course of the Second World War, the experience of British cities to aerial bombardment by the Luftwaffe varied in intensity (Rugg 2004, 153). The damage, however, was uneven and relatively light in comparison to cities in Germany attacked by the air forces of the Allies (Larkham 2005, 4). Following the Battle of Britain in 1940, the main focus of the Luftwaffe's bombing offensive was London. The raids on the capital accounted for approximately one-third of British civilian war casualties (Rugg 2004, 153). It is unsurprising, therefore, that the historiography of the Luftwaffe's campaigns over the UK focuses on the Battle of Britain (Overy 2000; Overy 2010; Ray 1996; Cox 1990; Levine 2007) and the London Blitz (Calder 2008; Harrisson 1976; Fitzgibbon 1957; Moshenska 2010; Bell 2008; Hanauer 2014). A growing body of work, however, has started to highlight the destruction suffered by other British towns and cities (Hodgson 2015a; 2015b; Price 2000; Flinn 2008; Johnson 2005). One of those cities is Norwich, in the county of Norfolk (Banger 1989; Bowman 2012), which is the focus of this article.

The author selected Norwich to trial a new approach at reconstructing historic flightpaths because its 'Bomb Map' survives (NRO ACC 2007/195). This map was maintained during the Second World War by the City Council's Engineer's Department, forming part of the 'Bomb Census' established by the government to provide an

overview of air raids on the UK. Norwich was one of the cities targeted by the Luftwaffe during the Baedeker Raids of 1942 so it also serves as a case study for the wider context of raids on the UK. A letter from Air Chief Marshal GD Harvey, Fighter Command, to the Air Officer Commanding-in-Chief, Bomber Command, dated 9 August 1942, states that Norwich 'had been subjected to more air attacks than most cities in the country' (Figure 2) (TNA AIR 13/42a). Norwich was bombed on various occasions and although it is uncertain whether Harvey was referring to the total number or the frequency of raids, sufficient information survives to allow new methods of analysing data from the Bomb Map to be tested.

Although the focus of this article is the plotting of anti-aircraft (AA) fire domes and the flightpaths of the Luftwaffe's aircraft in three-dimensional space, it is important to note that Norwich was protected by a wider landscape of air defence. This included searchlight positions and 'Starfish' decoys (TNA WO 166/189a; Dobinson 2000, 90). The raids on Norwich and the city's defences also existed within the wider history of the Luftwaffe's tactics and strategy and the development of the UK's air defences. As both of these have been covered extensively elsewhere (Corum 1997; Corum and Muller 1998; Cooper 1981; Goss, Cornwell and Rauchbach 2010; Murray 1996; Mason 1975; Killen 1967 for the Luftwaffe, and for the UK's air defences Dobinson 2001; Pile 1949; Kirby and Capey 1997), they will not be discussed in this article.

Previous Approaches

One of the first attempts to examine the strategic placing of defences within a landscape using Geographical Information Systems (GIS) was Colin Lacey in his study of the Second World War Taunton Stop Line 'firesheds' (Lacey 2003). The use of 'viewshed analysis' and 'fields-of-fire' were used subsequently in a number of conflict archaeology studies (Drexler 2004; Rowe 2005; Athanson 2006; Gonçalves, Almeida, and Rua 2016). This body of work has demonstrated that GIS could be used for the spatial analysis of defence sites and can make significant contributions to understanding the siting of structures within the landscape (Rowe 2012, 200). Although these studies took into account three-dimensional topographical data, the fields-of-fire were displayed in a two-dimensional format (Rowe 2014, 357).

It was not until the work of Spennemann (2011, 335-337) that fields-of-fire were considered as a fire dome in three-dimensional space. In two articles, Spennemann, and then Spennemann and Poynter, employed three-dimensional spatial visualisation in their interpretation of the Second World War Pacific island battlefield of Kiska (Spennemann 2017; Spennemann and Poynter 2019). Their methodological approach combined the depressed AA gun elevation with weight of ammunition, rate of fire and the number of guns in an emplacement to estimate AA fire in three-dimensional space (Spennemann and Poynter 2019, 2463). These articles demonstrated that AA fire domes had significant benefits for analysing airspace compared to plotting gun positions on a map (Spennemann 2017, 218). One particular advantage of mapping airspace is its ability to 'both simulate known flight/attack routes and query to what degree they would have been exposed to AA fire' (Spennemann and Poynter 2019, 2476). In 2018, Sprague

attempted to develop a predicative model for locating B-29 crash sites on the Pacific Island of Saipan by plotting three-dimensionally the approach zones to airfields (Sprague 2018, 128). These zones, however, were defined generically and did not take into account the actual flightpath of individual aircraft.

This article takes the concepts developed by Sprague, Spennemann and Poynter, and applies them to an urban area in the European Theatre of Operation during the Second World War. It combines the airspaces of offence and defence into a more complete assessment of an aerial battlefield. The reconstruction in this article is based on simplified AA fire domes centred on gun batteries, created using the maximum range of the guns deployed. The article will also present a new approach that attempts to plot the flightpaths of bombers in three-dimensional space during their bomb runs.

Reconstructing Norwich's Defensive Airspace

The first raid on Norwich during the Second World War occurred on 9 July 1940 and involved two aircraft that approached Barnard's wire factory on Mousehold Heath from the northeast at 600ft (185m) (Banger 1989, 12). Not only was there no warning of the raid, the aircraft remained in the area, unopposed, for approximately one hour (TNA HO 199/63, 3). At this time, Norwich was protected by two 'QF 3-inch 20cwt' AA guns crewed by 286 Battery, 91st Heavy Anti-Aircraft (HAA) Regiment Royal Artillery (RA), with an effective range of 16,000ft (4,900m) (TNA WO 166/2382a; Routledge 1994, 13). There were also

> 'two machine-gun emplacements near-by [that] were not manned [during the raid] … [and the] men [of Barnard's] were very bitter that there had been no anti-aircraft fire or fighters to drive off the raiders' (TNA HO 199/63, 1).

Following a number of raids without warnings, it was decided that a series of 'spotters' should be employed at favourable positions around the city 'to keep an eye on the sky and signal a warning should they observe any indication of hostile activity' (TNA ZLIB 10/40, 1). Pooling resources, three companies - Boulton and Paul, Laurence Scott and Electromotors, and Reckitt and Colman - erected a scaffold stage for spotters on the roof of Carrow House, which was later in the summer replaced by an 85ft (25m) high steel pylon tower in the grounds of No. 15 Bracondale. Even though this tower offered unobstructed sky views (TNA ZLIB 10/40, 1, 3), attacks continued to occur with no alarm being raised, resulting in '[g]reat indignation … expressed by all classes of the public' (TNA HO 199/59a, 1).

> Norwich's AA guns went into action for the first time in August 1940:
> 'at first some alarm was created by the noise thereof, as soon as the population realised that they were guns and not bombs their confidence returned and in general the people … [were] happier now that they feel they have got some protection' (TNA HO 199/59b).

At this time, the guns were based at four locations, known as 'X', 'Y', 'H', and 'F', and were operated by 221 Battery, 91st HAA Regiment RA (TNA WO 166/2382b). Despite this increasingly defended airspace, however, enemy aircraft continued to raid the city throughout November and December. The enemy aircraft would peel off from

concentrated attacks on the east coast to bomb Norwich (TNA ZLIB 10/40, 4, 6). Raids continued until 8 August 1941, after which the city had a respite from bombing for a number of months (TNA ZLIB 10/40, 7; TNA WO 166/189b, 1; Banger 1989, 29).

By December 1941, it appears that Norwich's airspace was only defended by two AA positions: 'H2' and 'H3' (TNA WO 166/2396a). During that month, 106th HAA Regiment RA had begun preparations to dismantle H2's guns (TNA WO 166/2396b). On 3 January 1942, only four 3-inch guns were left to protect Norwich's airspace (TNA WO 166/7280a, 2). With a rate of fire of sixteen to eighteen rounds per minute (Routledge 1994, 13), their fire domes would only be filled with a modest number of shells. Additional defence by three Bofors and three Lewis guns was provided to the airspace around RAF Horsham St Faith, on the northern edge of the city (TNA WO 166/7280b, 8). These guns were only intended for localised defence, as the Bofor's optimum engagement range was only 1,500yds (1,372m) (Routledge 1994, 52).

By April 1942, AA guns were deployed to sites H1 and H2 (TNA WO 166/7281a). During this month, the Luftwaffe selected Norwich as one of the targets of the 'Baedeker Raids', a series of attacks on undefended or lightly defended British towns of cultural significance following the RAF's raid on Lübeck, Germany. On the night of 27 April, between 25 and 30 aircraft dropped flares onto the city from heights between 3,000ft (914m) and 4,000ft (1,219m). Following a short pause, one aircraft at a time, flying west to east every two minutes, dropped bombs over the city (TNA HO 191/184, 1). During this raid, H1 claimed to have destroyed a Junkers JU88 at 2,000ft (610m) whilst H2 damaged one at 200ft (61m) (TNA WO 166/7281a). This is one of the few written accounts of Norwich's AA guns successfully shooting down enemy aircraft.

The following night, 28 April, approximately 40 aircraft attacked the city (TNA WO 166/7280c, 1). Approaching Norwich from the north at 23:13, the aircraft dropped flares, high explosives and incendiary bombs. These two raids resulted in, according to one source, the deaths of 196 people and damage to 14,000 houses, of which 1,200 were destroyed (TNA HO 199/98a, 3). Compared to the previous night, the opposition from ground defences was more pronounced, forcing the attackers to fly at higher altitudes (TNA ZLIB 10/40, 9). In total, Norwich's HAA batteries fired 315 3.7-inch and 465 3-inch rounds, whilst the light Anti-Aircraft guns fired 80 rounds of 40mm (TNA WO 166/7280c, 2).

In the aftermath of the Baedeker Raids, AA Command decided that certain towns needed stronger AA protection (TNA WO 166/7280d), and Norwich was allocated twelve 3.7-inch mobile AA guns, with a range of 25,000ft (7,620m) (Routledge 1994, 57; TNA WO 166/7280e, 1 and Appendix). In addition, the city also received a balloon barrage (TNA HO 199/98b, 1). Connected to cables, the balloons were intended to force enemy aircraft to fly at higher altitudes, decreasing their accuracy and making them easier targets for the AA guns (Penny 1997, 2). By 2 May 1942, five days after the first raid, 993 Mobile Balloon Squadron had reconnoitred and deployed 22 balloons within Norwich's airspace. This number was increased to 36 by the end of the month (TNA AIR 27/2338a). It was the role of this squadron to

> ‘give general protection to the entire Norwich area, especially bearing in mind the low civilian morale incident upon heavy [sic] attacks at low level which occurred when the city was relatively undefended’ (TNA AIR 13/42b, 1).

These balloons were regularly flown over Norwich in the following months at a height of 6,500ft (1,981m) when the city was being attacked (TNA AIR 29/858).

Twelve days after the first Baedeker Raid on Norwich, thirteen Luftwaffe aircraft attacked the city again, having broken off from a group of 35 planes operating over northeast Norfolk. Flying at an average height of 4,000ft (1,219m), their bombs were widely dispersed around the city with few landing in the target area (TNA WO 166/7281b, 1). Surprised to find new defences, the Luftwaffe’s ‘bombs fell within five miles of the Norwich City boundary … [as] the bombers would not face the barrage which was very heavy’ (TNA HO 199/98c, 4).

In August 1942, just three months after the Baedeker Raids, however, the number of guns protecting Norwich’s airspace were reduced from twelve to eight 3.7-inch guns. These were presumably deployed to sites H2 and H3, the only sites referenced in the archives as active until February 1943 (TNA WO 166/7281e, 2; TNA WO 166/11213a). Although it was standard for AA guns to be deployed in groups of four, many sites were only allocated two, but had provision to double up (Dobinson 2001, 143). As these guns had an effective ceiling of 25,000ft (7,620m) (Routledge 1994, 57), the airspace above the centre of Norwich was now defended by two overlapping fields of fire (Figure 3), still supported by the barrage of 36 balloons introduced in May 1942 (TNA HO 199/98b, 1; TNA AIR 27/2338a).

On 23 February 1943, 383/86 HAA Battery vacated ‘H4’ and ‘H5’ to re-join their regiment. This indicates that, at some point prior, these sites had been operational. It was around this time that 1 Troop 188 AA ‘Z’ Battery briefly relocated to H5 (TNA WO 166/11213a), before returning to ‘NZH2’ on Mousehold Heath on 11 March (TNA WO 166/11213b, 1). The Z battery deployed solid-fuel rockets that had an effective ceiling of 20,000ft (6,096m) (Routledge 1994, 56). These were most effective when targeting mass formation of enemy aircraft (TNA WO 166/11143a, 1).

Together, H2, H3, H4 and H5 formed ‘Norwich[’s] defences [and] constitute[d a] “Baby [Gun Defended Area] G.D.A.” …. controlled by … N.H.2’ (TNA WO 166/11213c, 1). By November 1943, the number of 3.5-inch AA guns at these sites had increased to sixteen (TNA WO 166/11147, 3). At the end of 1944, work had begun to wind down the defences of Norwich’s airspace and by 31 October it was reported that ‘Sites Norwich H.2 and Norwich H.3 are unarmed’ (TNA WO 166/14827).

Reconstructing Luftwaffe Flightpaths

To provide a detailed three-dimensional reconstruction of aerial warfare, it is important to relate ground-based defences to the flightpaths of attacking aircraft. As mentioned earlier, Norwich City Council’s Engineers Department recorded bomb impact locations onto the Bomb Map (Figure 1), which allows some reconstructions of attack patterns. The Map records with pinned labels the location, type and date of 666 bombs dropped

on Norwich between 12 February 1940 and 30 March 1945. It is possible that pins have fallen out since the war and been replaced in the wrong position; in addition, there are 169 holes in the map representing missing pins and labels. Further, it is also uncertain whether unexploded bombs were recorded. Despite these issues, however, the Norwich Bomb Map is an important mapped visual representation of the landscape of aerial bombardment.

Cartographic representations of bombscapes do not take into account the vertical dimension of the battlescape. Bombs dropped by aircraft do not fall to the ground by a straight vertical trajectory: their path is actually represented by a concave curve. As a bomb travels along this path, it covers a distance known as the 'range' (Office of the Chief of Ordnance 1944, 3, 4). By taking into account the range of a bomb, it is possible to build a more accurate depiction of the Norwich aerial battlescape.

To calculate the range of bombs dropped from aircraft, it is necessary to determine the height at which they were released. Unfortunately, the altitudes of aircraft bombing Norwich were only recorded on six occasions: 2 August 1942 (TNA AIR 27/2338b), 5 September 1942 (TNA AIR 27/2338c), 5 December 1942 (TNA WO 166/7282, 1), 1 January 1943 (TNA WO 166/11143b, 1), 18 March 1943 (TNA WO 166/11213d) and 5 May 1943 (TNA WO 166/11144, 1). It is possible to identify the flight path individual aircraft on these raids through an analysis of the Bomb Map. When dropped from a single aircraft, bombs will generally fall in a linear arrangement known as a 'stick'. These will appear in the bombscape as a line of impact points spread over a distance. In determining sticks of bombs, it is important to know the type of bomb and the payload of the aircraft. The planes raiding Norwich, including the Heinkel He-111, typically carried four 500lb (227kg) bombs, or significantly more 50lb (23kg) incendiaries. By combining sticks of bombs, with aircraft heights and the range of bombs, it is possible to reconstruct part of the flightpaths of bombers through an airspace.

A simple visual analysis of the two-dimensional bombscape of 5 September 1942, as depicted on the Norwich Bomb Map, could be interpreted as the bombs being dropped in a single stick by an aircraft flying through overlapping HAA fields of fire (Figure 4). However, by reconstructing the planes flightpath through the airspace, a different story emerges. At the time, observers recorded that the plane flew at an altitude of 25,000ft (7,620m) (TNA AIR 27/2338c). Bombs dropped from this height had a range of approximately 11,000ft (3,353m) (Office of the Chief of Ordnance 1944, 4). By combining the range of the bombs with the altitude of the aircraft, it is possible to plot the bomb run of the plane in three-dimensional space, from which it is clear that the aircraft was actually flying outside of the optimum engagement range of the city's 3.7-inch guns (Figure 5).

The bombscape of 5 May 1943 could be interpreted as three aircraft flying in formation during their bomb run (Figure 6). If the same methodological approach of combining aircraft altitude with bomb range is applied to this raid, it is clear that the three aircraft were actually flying independently on different trajectories when they dropped their bombs (Figure 7). In this instance, however, it is not possible to determine the direction of flight of the planes with the information available.

Discussion

Over the course of the Second World War, Norwich's airspace underwent a series of changes due to the introduction of new technology and in response to the evolving nature of the threat posed by the Luftwaffe. The evolution of the city's airspace can be categorised into three phases: pre-Baedeker, Baedeker and post-Baedeker.

In the pre-Baedeker period, the Luftwaffe mainly targeted Norwich's industrial area in the vicinity of the Thorpe Railway Station and Carrow Works, and a small number of AA guns defended Norwich's airspace. By 1940, there were two 3-inch guns with fire domes extending 4,900m into the city's airspace. Norwich was also protected by two machine gun positions that were intended for localised defence. Although these defences would have provided overlapping fire domes covering the city's airspace, the number of shells that the guns could put up into the air was limited. The QF 3-inch 20cwt AA gun could only fire sixteen to eighteen rounds per minute (Routledge 1994, 13), so that the number of aircraft that could be targeted at one time was severely restricted, especially with only two guns deployed. Although the guns posed a limited military deterrent, they still had a role to play in maintaining morale: when deciding whether to fire, the 'desirability of the guns being heard by the civilians whom they are protecting is to be borne in mind' (TNA WO 166/7280f). Consequently, AA guns would be fired even when there was little chance of hitting enemy aircraft as it raised the spirit of those sheltering from the bombs (Jones *et al*. 2004, 477).

Against the limited defensive capabilities of Norwich's airspace, the aircraft of the Luftwaffe could operate with relative freedom. Up until the Baedeker Raids, the pilots were recorded as having conducted their bombing runs at heights between 500ft (152m) and 1,200ft (366m) (TNA ZLIB 10/40, 2, 6), with an average height of 850ft (259m). At these low levels, the bombers could aim more accurately at their target (Figure 8).

During the first of the Baedeker Raids on Norwich, the bombers flew at heights varying between 3,000ft (914m) and 4,000ft (1,219m) (TNA HO 191/184, 1). Although the city's AA guns fired 780 rounds during the second night (TNA 166/7281f), this would have been only approximately twelve minutes of continuous fire, assuming there were only four AA guns deployed firing sixteen to eighteen rounds per minute. The explosives and incendiaries dropped by the bombers on these raids were far more dispersed than the pre-Baedeker Raids bombscape. It appears that Norwich's industrial heart was no longer the target; the focus now being domestic housing areas (Figure 9).

In an attempt to combat the relative freedom of the Luftwaffe pilots to operate within Norwich's airspace during the Baedeker Raids, a balloon barrage and additional AA guns were deployed. The balloons were designed to make the 6,500ft (1,981m) of vertical space between the cables attaching them to the ground dangerous to the attacking aircraft. After the arrival of the balloons, observers recorded Luftwaffe pilots flying at heights varying between 200ft (61m) and 25,000ft (7,620m), with an average height of 6,281ft (1,914m) (TNA AIR 13/17, 1; TNA AIR 27/2338c). This was 5,431ft (1,655m) higher than the average height of enemy aircraft flying over Norwich in the

pre-Baedeker and Baedeker period. However, the presence of the balloon barrage clearly did not deter all pilots from operating within the airspace at low levels.

By increasing the number of AA guns deployed to Norwich, overlapping fire domes with high concentrations of fire protected the city's airspace. The combination of a balloon barrage and increased AA fire made the lower levels of Norwich's airspace more hazardous. By forcing the bombers to fly at higher altitudes, the city's post-Baedeker bombscape became more dispersed (Figure 10). This meant that the majority of bombs fell in an area of mixed industrial and domestic land coverage with only some landing near the industrial areas of Carrow Works and Thorpe Railway Station.

By combining bomb trajectories with impact locations, it is possible to reconstruct the flightpath of an individual aircraft's bomb run. When this information is combined with AA fire domes, it is possible to recreate the airspace of aerial warfare. This can shed light on the tactics used by both the city's defences and its attackers, but it only provides a visualisation of a snapshot of the battle. If in future bombscapes can be combined with additional data, such as the distribution of searchlights, logbooks of both bombers and interceptors, the archaeological excavation of crashed aircraft, ground based observation, mission briefings and after mission reports, it might be possible to accurately reconstruct the airspaces of historic aerial warfare. This would not only aid the studies on the strategic positioning of ground base defences, but also shed light on the effectiveness of the UK's defensive umbrella during the Second World War. In addition, by reconstructing airspaces it would be possible to examine the interplay between attacker and defender in more detail.

Conclusion

Aerial warfare exists in a 'unique three-dimensional battlefield' (Young 1990, 62). The Italian theorist of air power General Giulio Douhet, wrote in 1921 that the 'airplane has complete freedom of action and direction; it can fly to and from any point of the compass in the shortest time – in a straight line – by any route deemed expedient. Nothing man can do on the surface of the earth can interfere with a plane in flight, moving freely in the third dimension' (Douhet, tr. Ferrari 1998, 9). The advent of AA technology was to prove Douhet over-optimistic. Because aircraft can operate in three-dimensional space, it is essential that when studying the aerial component of historic battles, the vertical element is considered.

In contrast to the archaeological traces of conflict that exists in the subterranean world (Weizman 2017, 254-8, Banks 2014, Barton, Doyle, and Vandewalle 2010, and Rodríguez-Gonzálvez *et al* 2015), aerial warfare leaves a ephemeral impact on the three-dimensional battlescape. Although the archaeological excavation of crash sites can reveal evidence for the final moments of an aircraft's flightpath, this was just one element of the plane's journey and a fragment of the battle. It is essential for the holistic understanding of aerial warfare that future studies recreate the vertical dimension of the battlescape.

By modelling three-dimensional airspace, scholars can explore data in new ways (Richards-Rissetto 2017, 16). This article illustrates the merits of visualising the vertical

element of aerial warfare by recreating Norwich's GDA and the flightpath of Luftwaffe bombers. In this reconstruction, the city's defensive airspace was presented as simplified fire domes representing the maximum extent of the deployed AA guns. Although not as accurate as Spennemann and Poynter's methodology, a simplified dome was sufficient for a visual representation of Norwich's defended airspace.

This new approach at reconstructing the flightpath of bombers, requires sticks of bombs to be identified in the bombscape. In the case of Norwich, this was aided by the survival of a Bomb Map that recorded the date and type of bomb dropped onto the city. By combining impact points with the range of the bombs, which is determined by the height of the plane at the point of release, as identified through archival research, it is possible to estimate the position of the aircraft in the airspace during its bomb run. Unfortunately, this methodology cannot determine the direction of an aircraft's approach. To enhance the reconstruction of flightpaths, it would be essential to conduct archival research to locate mission briefings, logbooks, or additional ground based observations.

Although this article has focused on the airspace of Norwich's Baby GDA (an essentially local airspace), it is important to remember that this was only one element of the national defensive airspace (Penny 1997, 1). Searchlights, fighter interceptors, radar and decoys also played an important role in the wider airspace of defence. The reconstruction of regional, or even national, airspace, incorporating all these elements, would allow an assessment of their relative contribution to the defensive umbrella. If the airspace of offence and defence was accurately visualised, it would be possible to assess whether they had an iterative reciprocal effect on each other.

By combining Spennemann and Poynter's fire domes with the new approach presented in this article for reconstructing the flightpath of bomb runs, airspaces of cities around the world that were bombed during the Second World War could be analysed. It may also be possible to apply this new approach to aerial combat during other periods of conflict. By combining Korean and Vietnam War logbooks with post-strike photographs, ground based defences and other archival sources, the airspace of a mission from take-off to landing could be plotted. Consequently, aerial warfare studies should continue to develop methodological approaches that reconstruct airspaces of defence and offence.

Notes on Contributor

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