

# Air and Space Power Review

Volume 22 Number 3 Autumn/Winter 2019

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Aerial Co-operation with the Navy  
Squadron Leader C H K Edmonds

## **Commander's Perspective**

Establishing the Air Truth  
Air Marshal (Retd) Sir Stuart Atha

## **Viewpoint**

An Ethics Framework for Autonomous Weapon Systems  
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## **Dissertation**

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Contributions from both Service and civilian authors are sought provided the submission is original and unpublished. Any topic will be considered by the *Air and Space Power Review* Editorial Board provided that it contributes to existing knowledge and understanding of air, space and cyber power. Articles should comply fully with the style guide published at the RAF Centre for Air and Space Power Studies website, <https://www.raf.mod.uk/rafcasps>; essentially they should be between 5,000 and 10,000 words in length, list bibliographical references as footnotes, and state a word count. Shorter articles and those which offer more of a personal opinion will also be considered for inclusion as a 'viewpoint'. A short biography and abstract should be submitted with each paper. A payment of £230 will be made for each full article published, or £100 for a published viewpoint and £50 for a book review. Additional constraints apply for payments to Service personnel for which details are available from the Editor.

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**ISSN:** 1463-6298

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**Print:** CDS

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# Foreword

by Group Captain James Beldon

To mark the centenary of the inception of the Gordon Shephard Memorial Prize Award, 2019's final edition of *Air and Space Power Review* begins with the re-publication of the inaugural prize-winning essay, *Aerial Co-operation with the Navy*, written in 1919 by Squadron Leader Charles Edmonds DSO (who retired from the Service as an Air Vice-Marshal in 1945), and first published by RUSI in 1923. His essay reflects upon the importance of aerial-maritime co-operation and early interoperability in the period immediately following the First World War. An air-maritime expert and practitioner (he served in the Royal Naval Air Service before the formation of the Royal Air Force in 1918), Edmonds' essay examines co-operation with the Royal Navy's Battle Fleet, commerce protection, denial of an adversary's commerce and support of expeditionary operations overseas. Particularly prescient is his observation that '...we are most unlikely to find ourselves placed in so favourable a strategic position as in the late War...' – wise insight for a country that would itself be subjected to a campaign of attempted strategic strangulation by Hitler's U-Boat force in the Second World War. There are, equally, many lessons that remain pertinent a century after Squadron Leader Edmonds first put pen to paper.

In his 'Commander's perspective' article, *Establishing the Air Truth*, Air Marshal Sir Stuart Atha reveals the ten principal air power 'truths' he has distilled from his long and distinguished career on the Royal Air Force's front-line. Forged through the experience of many warfighting operations, both as a pilot and senior commander, he does not underplay the value of experience, but appropriately emphasises the central importance of the conceptual component of fighting power. This article is essential reading for all members of the Royal Air Force, and especially those who aspire to (or already have) the privilege of command.

The rapidly evolving sphere of autonomous weapon systems, and the proposed need for an ethical framework regarding their employment, form the basis for Professor Peter Lee's thought-provoking article, *An Ethics Framework for Autonomous Weapons Systems*. He persuasively argues that technological, political and operational aspects must be considered as a whole if a viable ethical framework for the application of autonomous weapons systems is to be developed and applied, whilst according with international humanitarian law.

The first of this edition's Chief of the Air Staff's Fellowship Dissertations, by Flight Lieutenant Tom Raeburn, explores Russia's employment of hybrid warfare during its illegal invasion of Ukraine in 2014. The speed and apparent ease of Russia's annexation of Crimea demonstrated the deployment of a potent new approach to war, underpinned by information dominance.

The disbandment of the Tornado GR Force in early 2019 brought to an end the service of an aircraft renowned as the bedrock of the Royal Air Force's fast-jet fleet for almost four decades. Wing Commanders James Heeps of IX(B) Squadron and Matt Bressani of 31 Squadron reflect on their experiences as the final two Tornado squadron commanders, and bringing this mighty warrior to its operational conclusion over Iraq and Syria some 37 years after its introduction to front-line service.

Flight Lieutenant Peers Lyle delivers a thought-provoking Trenchard Fellowship dissertation addressing the evolving use of 'Commercial-off-the-shelf' drones by violent extremist organisations. The increasing accessibility of this capability allows extremists to challenge the traditional dominance of air power, which has long been the privilege of affluent state powers, and examines the potential far-reaching consequences for the future operational environment.

The final article in this edition focuses on the enduring need to provide early warning, and specifically examines the application of scientific resources available to the Royal Air Force during the inter-war period. In his article, Mark Russell examines funding lines, innovation and the application of emerging technologies which eventually led to the development of radar; this case study reflects upon some of the historical challenges that provides helpful insight that could apply to more contemporary capability development challenges.

Our first book review, *'Global Defense Procurement and the F-35 Joint Strike Fighter'*, charts the origin and development of the F-35 Lightning. The author examines each of the key international partners in turn, and offers a relatively balanced appraisal of a programme which normally generates strongly held, if not always substantiated, opinions.

In *'Goliath: Why the West doesn't win wars. And what we need to do about it.'*, Professor Sean McFate characterises Western militaries as prisoners bound to the industrial age strategies of the Second World War, criticising big ticket procurement programmes and their potentially perceived lack of utility against non-state foes.

Our final book, Thomas Wildenburg's *'All the Factors of Victory: Admiral Joseph Mason Reeves and the Origins of Carrier Airpower'* contains a biographical insight into a US naval aviator who, the author declares, 'laid the foundations for all of the major tenets of modern carrier doctrine'. The author identifies that Reeves' career was supported by the three equally important pillars of education, training and experience. It is an appropriate note on which to end this edition, and chimes very well with the 'truths' revealed by Air Marshal Sir Stuart Atha earlier in the volume. It also marks the final entry in the final edition of *Air and Space Power Review* under

my editorship. Thank you to my team at the Directorate of Defence Studies for all they have done to maintain this journal's excellent quality and reputation, and thank you also to all of the contributors and readers who have made this role so worthwhile.

Enjoy reading this edition, and remember that we are always in search of new perspectives that advance the Royal Air Force's conceptual development, irrespective of rank or experience. Additionally, I should highlight our Facebook and Medium pages, with which you can interact directly via the following links:

<https://www.facebook.com/RAFCASPS/>

<https://medium.com/raf-caps>





# The Royal Air Force Centre for Air and Space Power Studies Academic Awards 2019

The Royal Air Force Centre for Air and Space Power Studies (RAF CASPS) Academic Awards for 2019 were presented on 17 July during the Chief of the Air Staff's Air and Space Power Conference held at the IET Savoy, London. The presentations were made by Air Chief Marshal Sir Stephen Hillier in front of over 400 delegates comprising visiting air chiefs, academics, members of the civil service and service personnel, both regular and reserves.

## The Gordon Shephard Memorial Prize

The Gordon Shephard Memorial Prize is awarded in memory of Brigadier General G F Shephard DSO MC RAF. Awarded annually since 1919, previous winners include Flight Lieutenant Slessor MC (1923), Wing Commander Leigh-Mallory DSO (1930) and Squadron Leader Graydon (1974). The prize is awarded to an RAF airman or woman for the best Service paper or essay published through RAF CASPS.

The recipient for 2019 was Group Captain Rob O'Dell, who is currently serving in the ISTAR Force Headquarters and is one of the Chief of the Air Staff's academic fellows, undertaking a part-time PhD examining Cold War maritime operations – an area of contemporary interest. His paper, 'The Cold War Cinderella Service: RAF Maritime Patrol Aircraft Operations Since 1945' was published in *Air Power Review* Volume 21 No 2. The paper explores RAF Maritime Patrol Aircraft and Operations, providing an overview of the period immediately following World War Two until the capability was withdrawn from service in 2010.



## The Salmond Prize

The Salmond Prize is awarded in memory of Sir John Salmon who, as an Air Chief Marshal, was appointed CAS in succession to Marshal of the Royal Air Force Sir Hugh Trenchard in 1930. The Prize is awarded annually for the best essay on an air power topic submitted to RAF CASPS by a civilian or non-RAF serviceman or woman of any nationality.

The recipient for 2019 was Wing Commander (Retd) Sophy Gardner. Her paper, 'The Prophet's Interpreter: Sir Samuel Hoare, Hugh Trenchard, and their Campaign for Influence', was published in *Air Power Review* Volume 21 No 1. It provided a fascinating insight into the development of the RAF's culture in the period following its formation, and the pivotal relationship that was forged between Trenchard and his contemporary, the long-serving Secretary of State for Air, Sir Samuel Hoare.



## The Air Power Defence Research Paper Prize

The Air Power Defence Research Paper (DRP) Prize is awarded annually to the Advanced Command and Staff Course graduate who produces the best air power related DRP.

The recipient for 2019 was Wing Commander David Tait, currently serving in the Carrier-Enabled Power Projection team at the Ministry of Defence. His DRP, 'The Utility of Cross-Domain Operations' was a sophisticated and convincing analysis of the UK and its key allies. Offering insightful observations on the strategic preferences of other nations, the DRP made a genuine contribution to understanding the challenges and opportunities for the UK.



## Essay

# Aerial Co-operation with the Navy<sup>1</sup>

By Squadron Leader C H K Edmonds DSO OBE Royal Air Force

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**Biography:** Air Vice-Marshal Charles Humphrey Kingsman Edmonds CBE DSO served in the Royal Air Force between 1919 and 1945. He initially served in the Royal Navy as an aviator during the First World War, taking part in the Cuxhaven Raid in December 1914. While serving in the Gallipoli Campaign, Edmonds was the first man to sink an enemy ship from an aircraft, using a torpedo. In 1922 he was one of the first instructors at the RAF Staff College, and in 1929 was once again awarded the Gordon Shephard Memorial Prize for an air power essay.

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Editors Note: This essay was originally published by RUSI in Journal 66, Issue 462, 1921, under existing Crown Copyright ©. Republished by the Taylor and Francis Group in September 2009, the editors have kindly given permission for the reproduction of this inaugural prize winning essay, written in 1919 by Sqn Ldr C H K Edmonds, (Retd AVM CBE DSO), to mark the centenary of the Gordon Shephard Memorial Prize Award.

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<sup>1</sup> This was the winning Essay for the Gordon Shephard Memorial Prize, provided by the income from a sum of money placed at the disposal of the Air Council by Sir Horatio Hale Shephard in memory of his son, the late Brigadier-General G S Shephard DSO MC Royal Air Force.

"He who will know what shall be in the future must study what has been in the past".

– *Old Proverb.*

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### Introduction

**T**he object of a nation at war is to stop the enemy's national life, and the strategic plan which either belligerent follows to achieve this end may be divided into three classes, viz, naval strategy, military strategy, and independent air strategy.

When aircraft are employed for reconnaissance over the sea and in co-operation with the Navy the objectives must be the same as those which are the aims of the naval strategy, hence the use of aircraft against any other objectives comes under the heading of independent air strategy, or possibly military strategy, and is outside the scope of this paper.

Now the object of naval strategy is the control of maritime communications, and the destruction of the enemy's battle-fleet is the principal means to this end. The subject may be conveniently considered under the three following headings:

- (a) The Battle Fleet.
- (b) Commerce protection and prevention of the enemy's commerce.

- (c) Support of military expeditions overseas.

In Chapters I, II, and III the use of aircraft in the late War in co-operation with the Navy under the above three headings will be examined and some criticisms offered. In Chapter IV the limiting factors of various types of aircraft will be considered in conjunction with the probable requirements of future naval warfare. From this a forecast will be made of "the possible future of the various types of aircraft in a war against a first-class naval power".

Whenever "The War" is mentioned the late world conflict is meant. And the phrase "the future", unless specially stated, refers to the next ten years, for the author considers that the progress of aeronautics may be so rapid as to render impracticable conjectures beyond that period. No attempt has been made to discuss the work of aeroplanes and kite balloons in any detail, as they are not included in the "Definition of Subject" given in AMWO 915 of 14th August, 1919.

## Chapter I

### Co-operation with the Fleet in the North Sea

*Evolution of the Aeroplane Carrier.* On the outbreak of war very little was known of working aircraft from ships, therefore the solution of the problem of how to provide aircraft for the Fleet at sea was at once energetically sought.

Two classes of seaplane carrier were tried: a large ship with considerable stowage space for machines and considerable radius of action, and smaller ships with correspondingly less radius and stowage. In the former class was the old Cunarder, the "Campania", for use with the Grand Fleet; and in the latter class were the "Engadine", "Riviera" and "Empress", all three cross-Channel packets.

By December the three last-named ships had joined the Harwich Force, and on Christmas Day, 1914, a successful air raid on Cuxhaven and Wilhelmshaven was made by the seaplanes from them. This popularized such operations. The three existing carriers were fitted with improved accommodation for seaplanes, and others of a similar class were taken up.

When the refitted ships rejoined the Harwich Force, however, attempts to make similar raids led to repeated failures and disappointments. It was found that the North Sea in average weather was too rough to permit of seaplanes being hoisted out and in. Also surprise was practically impossible because the flotilla on passage to the German coast was almost invariably observed by Zeppelins, which the low performance seaplanes were quite incapable of bringing down. The seaplane carriers, too, had only a speed of about 19 knots, consequently it was very risky to keep them near the enemy's coast once they had been observed. Therefore, the policy of raiding the enemy's naval bases continuously was abandoned, and no more than sporadic attacks were afterwards attempted.

HMS "Campania" joined the Grand Fleet in the summer of 1915. Experience with her, confirming that gained with the Harwich Force, was that the use of aeroplanes from ships at sea was impracticable, that an aircraft carrier must have a speed at least equal to that of the ships with which she works, and that there was a need for both the large and the small class of carrier. Further, this experience enabled the Commander-in-Chief to lay down his aerial requirements for the Fleet at sea as follows:

- (i) To prevent reconnaissance by Zeppelins.
- (ii) To reconnoitre the enemy's fleet.
- (iii) To spot for gunfire after the battle was joined.

Accordingly the pre-war experiments in flying seaplanes with wheels, or aeroplanes, off the deck of a ship steaming at high speed into the wind were pressed on, and the results were good. In the meantime the possibility of an aeroplane alighting on the deck of a ship under way became recognized, which obviated the necessity of stopping to hoist-in after a flight, with the consequent risk from submarines. The construction of HMS "Argus", with a special alighting deck, began in 1916. In the autumn of 1917 successful trials of landing an aeroplane on HMS "Furious" were carried out, also the practicability of flying an aeroplane off a turret had been proved; and from this date onwards aeroplanes were carried on ships in lieu of seaplanes.

*Grand Fleet's Aircraft.* At the time of the Armistice a comprehensive programme for Grand Fleet aircraft was nearly completed. There were two large aeroplane carriers ("Furious" and "Argus") and one small one ("Vindictive") whilst two more large ones were under construction. "Argus" had torpedo machines, the other carriers reconnaissance machines.

In each light cruiser, except when prevented by questions of stability, a single-seater fighter was carried, whose primary role was the attack of Zeppelins.

Each battleship, or battle-cruiser, carried two seaplanes. These were either single-seater fighters or two-seaters, so distributed that each squadron of ships had its own planes for spotting or reconnaissance, and fighters to protect them.

This use of aeroplanes for overseas flying was necessary, because no seaplane existed which had the necessary performance to permit of flying off platforms, or of landing on a deck, or to bring down a Zeppelin. Nevertheless, there were certain unavoidable drawbacks. Even with air-bags and hydrovanes on the chassis, the strain on the pilots and observers and the wastage of machines was greater than if seaplanes could be used. Also, to keep the personnel in practice, there must be aerodromes, lighters for landing and embarking machines, etc, at each Fleet base. In the War these drawbacks were not prohibitive, because as the overseas flying was only occasional the strain on the personnel was never very great, neither was the wastage

excessive, as the aerodromes and shore organization could be easily provided. In peace, however, or in a war where the Fleet was more at sea, the same methods might not work. This matter will be dealt with further in Chapter IV.

Kite balloons were carried in a proportion of the cruisers, TBDs and battleships, being used respectively for reconnaissance, anti-submarine work, and control of gunfire. Considering that a great division of opinion existed as to the value or otherwise of the balloons, and that shortage of either men or material, or both, was always a difficulty throughout the War, the author considers that once the aeroplane programme was accepted the kite balloons should have been given up, except in a few destroyers for anti-submarine work. Airships of sufficient performance to meet the Fleet's requirements were not available during the War.

*German Aircraft in the North Sea.* Having reviewed the development of aircraft with the Grand Fleet, it is appropriate to consider the enemy's naval aerial resources, before passing on to a more detailed examination of their employment. Unlike ourselves, the Germans started the War with an efficient service of large rigid airships, whose primary role was the patrol of the south-east corner of the North Sea. They were based on Tondern, Altona and Cuxhaven, and it is no exaggeration to say that in the region of their patrols they held the supremacy of the air. Hence, the German Fleet when at sea in good weather always enjoyed aerial co-operation, the movements of any ships were nearly always screened by airships, whose great radius of action, speed range, and long endurance rendered them capable of this work.

The airship patrols were supplemented by seaplanes from Sylt, Heligoland, a station near Cuxhaven, and Borkum. Flying-boats were not used, but the German float-seaplanes were much superior to our own. They had no aircraft carriers, neither were aircraft carried aboard warships. Presumably the enemy relied on his large airships to fulfil the requirements of the Fleet at sea.

*Narrative of Events in the North Sea, with some observations and criticisms.* A brief review will now be made of the work of the Grand Fleet and Harwich Force, in order that the work of aircraft co-operating with them may be examined. Generally speaking, the guiding policy for our Fleet was to keep the majority of ships in harbour, and to carry out continual sweeps of varying strength with the remainder. Early in the War, as already mentioned, there were no aircraft to co-operate in these sweeps, which extended far beyond the range of our aircraft working from shore bases. The direct result was that the enemy's Zeppelins, being entirely unopposed, were in a position to warn their outlying small craft; if the sweeping force was small it ran the risk of interception by a superior force suitably guided by information from the air; if the sweeping force was strong this fact was reported, and the enemy was not to be enticed out. In any case the sweeps were far less effective and much more risky than if aircraft had been available.

The only offensive operations made by the enemy's ships were three similar sweeps, during which towns on our east coast were bombarded. On only one of these occasions were we able



to intercept the raiders by our surface ships and submarines. Had there existed on our side a more extensive system of air patrols, airships at long range, and seaplanes and aeroplanes closer inshore it seems that our Fleet would certainly have had a much better chance.

It was in January, 1915, that our battle cruisers intercepted the enemy's, who were probably embarking on one of these sweeps. The running fight of the Dogger Bank took place, in which two enemy battle cruisers were sunk and one seriously damaged before they could escape behind their minefields. This gives an excellent example of an opportunity for torpedo-carrying aircraft, had they been available. One hit on each ship with even a 14 inch torpedo would probably have so reduced the squadron's speed that all would have been overtaken and sunk.

In May, 1916, the Battle of Jutland took place. As is well known, before a superiority could be brought to bear, the German Fleet turned away under cover of a smoke screen and a failing light, and escaped a decisive defeat. On neither side were aircraft available in any numbers, yet the action is of interest by reason of the work which the few aircraft did, and more especially by reason of the proof it provides of the imperative necessity for air work in a fleet action.

The seaplanes in HMS "Engadine" were the only aircraft available for the British. One of these sent by wireless an accurate report of part of the German Fleet before the action commenced – information which light cruisers could only have obtained after considerable fighting. The author believes, but does not know definitely, that during the battle the German airships patrolled to the southward of the High Sea Fleet, watching its line of retreat. On the morning following the battle they did valuable work in reporting our Fleet's position.

Two points are made strikingly evident by the official despatches and Lord Jellicoe's book, "The Grand Fleet". The first point is the uncertainty in the C-in-C's mind as to the position of the enemy, after receiving a few reports from the battle cruisers; in other words, insufficient reconnaissance. The second point is that until about twenty minutes after the enemy had turned away, the C-in-C was unaware that they had done so, and to this their escape seems largely due. Again, insufficient reconnaissance. Any aircraft flying above the mist and the smoke might well have reported the turn immediately it was made.

After the Battle of Jutland the enemy abandoned any idea of an active policy for his High Sea Fleet, and concentrated on the submarine campaign. Accordingly, we greatly extended the Heligoland Bight minefields, and in connection with the mining, long reconnaissance flights from Killingholme, Yarmouth, and Felixstowe were made as often as possible by flying-boats. The chief object of these flights was to ascertain if and where the Germans were sweeping. At the end of the War the F2As were capable of patrols measuring 400 miles on the chart, but this only took the reconnaissance about half-way across the Bight, and the need for longer range aircraft became increasingly evident. This was emphasized during the last few weeks when a final sortie by the High Sea Fleet was confidently expected.

An interesting point in connection with these long reconnaissances was the difficulty of accurate navigation over the sea, and the need for developments in this direction. Obviously the more accurate the position of mine-sweepers reported, the more valuable the report.

Whenever the flying-boats were near Borkum, considerable fighting occurred with the German seaplanes. This led to development in flying the boats in strong formation, and of defensive armament and control of fire in the boats, which eventually enabled them to hold their own.

But to send a strong formation for each reconnaissance was most uneconomical, thus showing the need of a moderately manoeuvrable seaplane of high performance, which, though not intended for offensive fighting, could look after itself if attacked (A). These machines would have undertaken the work near Borkum, and the flying-boats would have undertaken the longer range work, the latter of necessity avoiding areas where opposition was likely to be very heavy. Such a machine, the "Fairey", with a Rolls-Royce engine, was produced just before the Armistice. There was much controversy on this subject, one school of opinion declaring that aeroplanes could do the work. It is, however, significant that those actually employed on continuous long-distance overseas flights (frequently over minefields) were emphatic that seaplanes or flying-boats, providing, as they do, more chance of safety in case of engine failure, are essential. Where the flights were less frequent and the strain consequently less, as in the Grand Fleet, the use of aeroplanes was satisfactory.

Whilst the large flying-boats, sometimes extending their radius by the use of lighters, confined their activities to the southern part of the "prohibited area", a number of reconnaissances over the northern part, and a raid against Tondern, were made by aeroplanes from the "Furious". The aeroplanes in light cruisers also, from time to time, had chances of attacking Zeppelins. In these operations it became evident that although the large airship falls an easy prey to an aeroplane that brings it to action, yet the action is often most difficult to bring about, because the airship can generally make a reconnaissance without coming very close, and if pursued can often escape in clouds of fog. Critics of the airship are much too prone to make capital out of the number of German airships destroyed over the North Sea (actually only six!), whilst forgetting the countless occasions on which they did valuable work without molestation.

The reconnaissances made latterly by machines from the "Furious" had an excellent effect on the morale of the Fleet's flying personnel, and in the Tondern raid gave a fine return in material damage done, but unfortunately the extent to which the minefields had now increased, put most objectives out of range. It is interesting to examine the good results which would probably have followed if more aeroplane carriers had been sanctioned along with the "Argus" in 1916, whereas actually it was nearly a year later that "Furious", "Vindictive", etc, were sanctioned, and at a time when there was very little more data than in 1916 regarding the capabilities of aeroplane flying off and on to ships, and when the pressure on the shipyards had increased. Had more carriers been available earlier, before the great expansion of the minefields in 1917, continuous air raids on a small scale could have been made. Their object

would have been to keep the enemy occupied, to collect information, and to keep up an offensive. If the development of the torpedo aeroplane, whose possibilities were proved at the Dardanelles in 1915, had received the attention it deserved, these machines would have played an important part in such raids, which might have been developed into the landing of raiding parties on the Frisian Islands, etc. Actually, however, the enemy enjoyed complete immunity from attack on his seaboard, he was thus able to decrease his defensive measures to a minimum, and concentrate on the offensive submarine campaign. Perhaps also the earlier provision of more fast carriers would have enabled the enemy's air patrol to have been neutralized. Efforts were made in this direction with the "Vindex" and "Manxman" in the Harwich Force, but their low speed and inferior carrying capacity prevented success.

The author considers that our inability to raid the German seaboard with ships and aircraft, and the fact that until the end of the War we lacked efficient aircraft with the Fleet, handicapped us and helped the enemy (whose airships provided the aerial co-operation which we lacked) to an extent not fully realized at the time. Had our Fleet not been so handicapped the War might have been considerably shortened.

## Chapter II

### Commerce Protection and the Prevention of the Enemy's Commerce

*The Blockade.* To the stoppage of the seaboard commerce of the Central Powers, their collapse and our ultimate victory were largely due. Their stoppage was accomplished by means of the blockade, based on the right of search, which necessitated the examination of all ships entering or leaving the North Sea by the Dover Straits or round the North of Scotland.

A minefield across the Straits of Dover compelled merchantmen to enter the Downs, where examination took place, and rendered this part of the blockade comparatively simple. But the Northern Patrol was a much more difficult proposition, involving as it did the watching of a line of some six hundred miles, from Scotland to Iceland, and thence to Greenland, where the weather was of the worst and submarines were a constant menace to the patrolling ships. In June, 1918, the laying of a mine barrage from Scotland to the Norwegian coast was commenced. Primarily this was an anti-submarine measure, but it would also have helped the Northern Patrol, by forcing merchantmen to use certain swept passages.

In conjunction with the plan for this barrage a considerable aircraft programme was contemplated, which comprised the expansion of the existing seaplane stations in the Orkneys and Shetlands, the use of airships, and the allocation of aircraft carriers and kite balloons to the patrol. Actually the programme was never undertaken, for it was realized that the long nights, the bad weather, and the great distances required to be flown rendered the work beyond the capabilities of contemporary aircraft. Had the conditions been easier there can be no doubt but that the effect of aircraft would have been great. For instance, they would have provided a most economical method of locating merchant ships and directing

them to rendezvous where the searching craft would be. Again, they would have provided valuable protection for the patrol ships against submarines. In short, the great possibilities of the more efficient aircraft of the future in connection with a maritime blockade were clearly shown.

The activities of the German cruisers, such as the "Emden", and their raiders such as the "Wolf", merely emphasize the difficulty from which surface ships suffer in searching and patrolling, by reason of their limited speed and vision, as compared to aircraft. This amplifies the remarks made above concerning the use of aircraft in a maritime blockade. It is interesting to note that the "Wolf" used a seaplane, which is believed to have materially helped her.

*Anti-Submarine Warfare – General Description.* The German submarine campaign, and our anti-submarine war, can conveniently be considered in five phases. In October, 1914, the first submarine attack on an allied merchant ship was made; later the enemy announced that all shipping in a prescribed zone round the United Kingdom was liable to attack, and in January, 1915, the first merchant ship was sunk without warning. Meanwhile, our policy had been one of attacking submarines wherever they were reported, in so far as the very limited means available would allow. By December, 1916, however, the situation had become so serious that a special organization was established in the Admiralty to deal with it, and with its establishment the first phase ended.

The main feature of the second phase was that increased efforts were made to harass each submarine from the moment of leaving base until her return. During this phase Germany declared her policy of unrestricted submarine warfare, which virtually brought the United States into the War.

The third phase commenced with the inauguration of the convoy system in the spring of 1917, previously to which the trade had been directed by "routeing" or by "suspended sailings". It was the convoy system which, above all other methods, did most to prevent the success of the German submarine campaign, and it was in connection with the convoy system, above all other anti-submarine operations, that aircraft proved of the greatest value.

In the summer of 1917 the policy of intensively mining the Heligoland Bight began to take effect, and the fourth phase may be said to have begun. Its characteristic was the great extension of mining in the North Sea and Dover Straits. The final phase was inaugurated by the enemy abandoning his attack on merchant ships, recalling his submarines, mine-laying off our Northern Fleet bases, and apparently making all preparations for a large naval engagement.

The five phases referred to apply mainly to the waters round the United Kingdom. In the Mediterranean we followed the same methods, so far as resources allowed. The work of aircraft during these phases will now be examined.

*First Phase: October, 1914, to December, 1916.* During this period air stations grew up near every naval base at home and in the Mediterranean. Also a Wing was sent to Flanders during the first weeks of the War, which later became based on Dunkirk. It is doubtful if aircraft contributed much towards anti-submarine measures as were taken during this period, but experience was gained which helped greatly towards the aircraft being usefully employed when the inception of the anti-submarine division of the Admiralty led to the more vigorous measures of the later phases.

By the end of 1916 the force at Dunkirk had grown to a strength of about four Wings, composed of fighters, bombers, reconnaissance and photographic machines, and seaplanes. These were used continuously over Zeebrügge and Ostend, and it was proved conclusively that seaplanes are so handicapped by the weight and head resistance of their floats, that they cannot be used where the opposition from anti-aircraft guns and hostile aircraft is very strong.

*Second Phase: December, 1916, to March, 1917.* Immediately on the inception of the Anti-Submarine Division there followed a great increase in all anti-submarine measures, and co-ordination of the methods of their employment.

At Dunkirk the RNAS was continually augmented, until at the time of transfer to the RAF it consisted of a Brigade. Up to the closing months of the War constant reconnaissance and bombing of the Flanders naval bases was done. This reconnaissance, which provided accurate data of the extent to which submarines used the Flanders ports, was of great value.

As regards the bombing in April, 1918, 17.5 tons of bombs were dropped, while in August this had been increased to 98.8 tons. From the evidence available it seems that the material damage done was slight, probably one submarine was destroyed in Zeebrügge Docks, and in July, 1918, the lock gates at that place were probably burst. On the other hand, the enemy was forced to construct the most elaborate protection for the submarines, the constant alarms of raids must have retarded the refitting of the boats, and the effect on the crews necessitated their being sent into Germany for their leave. In addition to this, the enemy's very elaborate anti-aircraft organization must have absorbed great numbers of men and many aeroplanes, searchlights, etc, on purely defensive work.

The distinguished air officer who is best qualified to judge has estimated the relative value of the moral damage to the material damage done by the Independent Bombing Force as twenty to one. It is probable that the effects of the Dunkirk bombers and the bombing of Cattaro were similar. Certain it is, however, that aircraft provided the only means of attacking submarines in their bases.

All this bombing was done by aeroplanes, and therefore falls outside the strict scope of this paper. Mention has been made of it, however, because it shows where the legitimate work of seaplanes ends and that of aeroplanes begins.

*Third Phase: March, 1917, to Midsummer, 1917.* The feature of this phase was the substitution of the "convoy" system for the previous system of "routeing". In the latter, merchant ships had been instructed, as far as possible, to keep clear of dangerous areas. Also trade was ordered to pass through one of the four "cones of dispersion", of which the apexes were Falmouth, Innistrathull, and Kirkwall. It was thought that the submarines would operate in these areas where the trade converged, and that it would be possible to patrol them adequately with every means available, including aircraft. However, this proved to be bad policy, for the increasing range of the submarines so magnified the cones that the patrolling craft were insufficient. This led to the introduction of convoys, by which system merchantmen were collected at certain ports, and then escorted to their destination. It will readily be seen that the new system presented great advantages over the old, especially for aircraft. Patrolling a large "cone of dispersion" for a periscope was indeed searching for a needle in a haystack, but convoying ensured that the flying was done where the submarine was most likely to be, and most likely to take risks.

To co-operate in the convoy system, air-stations were built up first of all in the Channel and on the East Coast, and later were extended to the Mediterranean, Irish Channel and French Coast. The USA took over the convoy work in Ireland, and the Canadians made stations in Newfoundland and at the mouth of the Gulf of St Lawrence.

The general organization was as follows: An Air Group was formed for each operational area. The headquarters of the Group was in immediate touch with the SNO and the local Base Intelligence Office, and also in telephonic and wireless connection with the air stations or sub-stations of the Group. This provided the rapid means of communication which experience had shown as essential. As regards the equipment of such a Group, this came to comprise airships, flying-boats, seaplanes, aeroplanes, and kite balloons. The functions of each of these in convoy work will now be examined.

*Airships for Convoy Work.* The SS Airship, virtually a BE aeroplane stripped of its wings and suspended under a small envelope, was the first type to be used. Early in 1918 it was superseded by SSZ, which had greater speed, duration, bomb-carrying capacity, and facilities for observation.

The SSZ was in turn being superseded by the twin SS. This type, whilst giving an all-round increase in efficiency, had the great advantage of twin engines, and consequent greater safety in the case of engine failure or adverse winds. Further, to meet the demand for increased performance, larger non-rigids of the coastal and North Sea classes were produced but never in great numbers.

Except for the R29, which helped in sinking the U115, no rigids were completed in time to play much part in the anti-submarine war, but had the War gone on they would probably have done important work in escorting convoys far into the Atlantic, for which purpose large airship

sheds were in course of erection in Ireland. As the submarines were gradually driven to work farther and farther from the coast, the problem of how to provide an escort when the convoy was out of range of the smaller types of surface craft and aircraft began to arise. The difficulties of flying aeroplanes from and back to a ship are so great that at present there is little chance of each convoy carrying its own aerial escort (except kite balloons), and for the future it seems that convoy work at a great distance from the coast will be the rigid airship's role.

The airship's greatest difficulty was that of providing adequate sheds. Finally, mooring out sites were selected for the smaller non-rigids, and this proved most satisfactory, the ships riding out gales of over 60 mph without damage.

Much criticism was levelled at the policy of employing airships. The great expenditure on the sheds was one argument, but this was largely met by mooring out. Another argument was based on the airships' inability to fly in strong winds, and although this was true in fact it was counteracted by the facility with which they flew by night or in foggy weather.

When escorting a convoy and a submarine is sighted, the airship on account of its low speed usually fails to get over the submarine with bombs before the enemy dives. Hence it is clear that the principal value of the airship is that it locates the submarine and frightens it into diving, whereupon the submarine's speed is so reduced that probably it cannot get into position to attack.

The great variation of speed facilities for observation, signalling, and accurate bombing make airships excellent for convoy work, though on account of their vulnerability this must be confined to areas which hostile aircraft do not frequent.

Very careful statistics were kept at the Admiralty of man power, etc, used up by the various anti-submarine arms in relation to the results achieved. By these the employment of airships was fully justified. In the author's opinion the only criticism that can justly be levelled is against the pre-war policy which so neglected airships.

*Large Flying-Boats for Convoy Work.* The large flying-boats very early proved their value, for they had the essential qualities lacking in smaller seaplanes, viz, excellent view, good bomb-carrying capacity, big radius of action, and reliable engines.

Compared to airships the boats could fly in much stronger winds provided they had calm water for the take off. With the convoy station-keeping was more difficult, but the high speed gave a better chance of bombing a submarine before it dived. They were also capable of escort work where hostile aircraft were met; for instance, the Dutch traffic from Felixstowe.

As regards disadvantages, the F2A suffered from extreme heaviness on controls, which was, however, largely rectified in later types. The chief disadvantage was the great requirements in

sheds and slipways; but as in the case of airships this was met by the expedient of mooring out. Although this was satisfactory in moderate weather, the machines were always exposed to the risk of a gale when they would almost certainly "fly" at their moorings and stave in the hulls. To render the large flying-boats really reliable when they are away from main bases where extensive slipways and sheds exist, some means of enabling them to ride-out gales in a sheltered anchorage must be found. Possibly an adjustable trailing edge by which the planes could be set to give no lift would meet the case. The author considers that this question of mooring is of great importance, and demands immediate attention (D). Some improvement was effected by keeping machines moored on lighters, but this did not entirely meet the case in really heavy weather.

*Seaplanes, Aeroplanes, and Kite Balloons for Convoy Work.* Several types of seaplanes, the Short, the Wright, the Sopwith Baby, etc, were used and all suffered from the bad view ahead, inevitable in a single-engined tractor, and insufficient bomb capacity. These disabilities, together with the fact that the seaplanes were often prevented from rising by a choppy sea, and also the necessity for reducing the number of types in production, led to the gradual elimination of the seaplane, whose inshore work was taken over by aeroplanes.

In turn these aeroplanes suffered from the same disadvantages as the seaplanes, except in the case of the Blackburn "Kangaroos", and in addition flying over the water, even with air-bags, imposed an extra strain on the personnel, and caused extra casualties.

This leads one to the logical conclusion that the type of heavier-than-air machine required for inshore anti-submarine work, say, up to about 30 miles to seaward, is a medium-sized amphibian with floats and detachable wheels, carrying at least one 500 lb bomb and either a pusher or twin tractor (C). Normally the machine would work from an aerodrome, but, if necessary, the wheels could be dropped, and she could alight on the sea and be capable of taxiing or rising again.

Kite balloons were extensively used with convoys, for they provided the only possible aerial escort when out of flying range of the shore stations. As in the Grand Fleet there was much difference of opinion over their value, and finally the majority held the opinion that they did more harm in giving away the position of the convoy than they did good as look-outs or as "scarecrows".

*Fourth Phase: Midsummer, 1917, to Autumn, 1918.* The feature of this phase was the great extension of mining and barrage work in the North Sea, the Dover Patrol, and the Straits of Otranto – the work of aircraft in this connection in the North Sea has already been described.

At Dunkirk seaplanes were originally employed for this. Their value lay in their ability to observe any change in the positions of buoys or surface nets, to act as "scarecrows" and force the submarines to dive into minefields, and to help hunting flotillas. Later the use of seaplanes had



to be abandoned because they were no match for the German fighter aeroplanes, and the overseas anti-submarine work was taken over by a squadron of DH4s with Rolls-Royce engines.

At the Otranto barrage most of the flying consisted of hunting in co-operation with the surface craft. Kite-balloons unquestionably proved their value, for, used at the extremities of the barrage area, they forced the submarine to dive before entering the area. Generally speaking, experience on this barrage led to the same conclusions as at home.

Seaplanes were found preferable on account of the reduced risk from engine trouble, but a certain number of aeroplanes were essential for weather when seaplanes could not get off, and to provide machines to get away quickly in response to urgent calls. That aircraft are a necessary part of a mobile barrage is proved. However, it was also proved that a mobile barrage is an extravagant method of using aerial and other resources, for after the Armistice it was found that the Otranto barrage had accounted for only one submarine.

*Last Phase: Autumn, 1918 – General Considerations.* Of this period little need be said. The enemy abandoned the attack on merchant ships, and concentrated on submarine mine-laying off our Scottish Fleet bases. To meet this all available aircraft were moved to the East Coast of Scotland and England, and employed with hunting flotillas and on patrols.

Throughout all the anti-submarine operations there was a constant demand for increased size of bombs, more accurate bombing, and better fusing. The fusing question was the most difficult, and remained unsolved at the time of the Armistice. What was required was a variable fuse, which the observer could adjust to whatever depth he required.

Intercommunication between aircraft and ships was another vitally important question. Visual signalling by Aldis lamps was proved the best, wireless only being used for long ranges. Especially abroad, however, many patrol craft carried only indifferent signallers, and in these cases dropped messages in watertight containers proved a good expedient.

Frequently aircraft failed in their attacks because a submarine heard their approach without seeing them and dived. Experiments were made to try and find a means of silencing both engine and propeller, but they met with little success, and it is hoped that the research will be continued on this most important question.

The destruction of a submarine by aircraft alone proved most difficult. Officially aircraft are credited with only twelve submarines, though the instances when they helped surface craft in successful hunts are numerous.

Undoubtedly the most effective role of aircraft in anti-submarine warfare was convoy work. This was proved by statistics in 1918, when of 7,000 convoys escorted by aircraft only six were attacked.

## Chapter III

### Support of Military Expeditions Overseas

*Dunkirk, Dardanelles, etc.* A considerable proportion of the anti-submarine work already described was in support of our numerous military expeditionary forces. However, in addition to this, certain other air work falls within the scope of this chapter, of which some of the flying on the Dover Patrol and that at the Dardanelles form the most important part.

The principal duty of aircraft, in this connection, on the Dover Patrol was to keep so close a watch on Zeebrügge, Ostend, and the eastern approaches to the Straits as to prevent the enemy's naval craft bringing off a raid in force against the cross-Channel communications of the Army in France. During the passage of the Expeditionary Force a seaplane patrol was maintained from Westgate to Ostend, and a mixed force of aeroplanes and seaplanes was sent to Belgium.

After the German occupation, however, the aircraft for the Dover Patrol were based on Dunkirk and Dover. It has already been stated that the great opposition necessitated the anti-submarine patrols and bombing being done by a squadron of DH4s with RR engines. Exactly the same conclusion was reached in the work of spotting for monitors, and reconnoitring (chiefly by photography) the enemy bases.

At the Dardanelles conditions were different. Enemy opposition was much less, calm water was nearly always available for the get-off, and hence throughout the operations seaplanes played an important part.

When the operations began in February, 1915, the only aircraft available on either side were seaplanes on HMS "Ark Royal", which were employed chiefly in locating the forts and entrenchments on the Peninsula. Later, both sides were reinforced by aeroplanes, and in May HMS "Ben-my-Chree", a small seaplane-carrier of high speed, arrived.

From this time onwards the presence of submarines necessitated "Ark Royal" (a ship of only eight knots) remaining in harbour. Her machines were chiefly employed in spotting for the monitors and blister ships against positions on the Peninsula. This work they did most satisfactorily, their performance being quite sufficient against the limited numbers of enemy aircraft and anti-aircraft guns. Spotting for ships was gradually developed, and together with the experience gained at Dunkirk led to the following definite conclusions:

- (1) The best intercommunication between plane and firing ship is by WT (but the wireless telephone gives a great promise for the future).
- (2) The clock system gives the best results.

- (3) With these aids a ship at anchor can fire sufficiently accurately to take on counter-battery work.
- (4) It is, however, risky to take on targets very close to our own troops ashore.

*Value of the Fast Seaplane-Carrier.* The work of "Ben-my-Chree" exemplified the great value of a fast seaplane-carrier, used as a self-contained highly-mobile unit. Wherever aircraft were suddenly required, this ship was sent. In July, 1919, her machines were spotting for the monitor "Roberts" against the Asia batteries. During the second landing in August they assisted in a dummy landing, as a diversion, near Smyrna; and later, in the same month, effectively used torpedo seaplanes in the Marmora and Dardanelles. When Bulgaria entered the war, "Ben-my-Chree's" machines reconnoitred most of the Bulgarian coast, and were used from the Island of Milo in demonstrations against Greece. Finally, when aerial reconnaissance of the approach to Egypt through Syria and Palestine (which were out of range of aeroplanes in Egypt) were urgently required in January, 1916, this ship was detached to the Egypt and East Indies stations. In each of these various operations it was found possible for seaplanes, judiciously employed, to compete with such moderate opposition as was found at first. The opposition invariably grew too strong later, but by this time the less mobile aeroplane units had had time to select their aerodromes, etc, and get to work. The simplicity of working seaplanes from a carrier, granted always the *sine qua non* of sheltered water, is very marked in comparison with the use of aeroplanes from an aeroplane-carrier, which must be both under way and head to wind.

Similar work was done by seaplanes in the operations on the coast of German East Africa, and also in the Red Sea, when in the spring of 1916 the Allied diplomatists were beginning to cast their flies over Mecca, and during the evacuation of North Russia in 1919. All of which proves not only the great value of the fast seaplane-carrier under certain circumstances, but also the value of the type of "fighter reconnaissance" seaplane already mentioned (see A, page 242).

*Future "Combined Operations" by Navy, Army and Air Force.* Now an opposed landing on the enemy's territory (which may be termed a "combined operation") or the defence of our own possessions against such expeditions, has been a very frequent employment for the fighting forces of the Empire throughout history, and would seem to be a probable task for them in the future. Moreover, it seems that the effect of aircraft on such operations will be great. Therefore, the subject may now be considered briefly in the light of war experience and of probable developments.

Let us examine the effect of aircraft on such an expedition in its various stages. The first point is that the selection of the base or advanced base will be largely governed by the range and characteristics of the defender's aircraft. Even if his aircraft were not very strong the base could hardly be as close to the actual point of landing as were Imbros and Mudros, or all secrecy would be lost.

If, however, the defender's air force was strong, and included large airships, to ensure secrecy during the preparations and embarkation of troops the base would need to be about 1,000 miles from the point of landing.

The next point is the air work during the voyage from the base to the landing. This will comprise aerial escorts against hostile aircraft, surface craft, and submarines. The relative distance between the base or advanced base and point of landing must largely decide what types of aircraft are used for these duties, and whether they work from aircraft carriers or shore bases.

The effect of the defender's air patrols might be considerable. For instance, if it was intended for the expedition to approach the coast after dark, and land by night, a machine patrolling to seaward in the previous afternoon might discover the whole expedition, and to retain any chance of surprise the attacker's air force must shoot down that machine, not merely drive it off. Probably, too, the defenders would have coastal aeroplane patrols in the evening, which would prevent the expedition approaching to very near the coast before dark, and might be a considerable handicap at a season when nights were short.

The provision of the necessary flying for covering the landing, and immediately after, presents considerable difficulties for various reasons. First, because the number of aircraft carriers would probably be limited, and there might be difficulties against keeping them under way or even anchored head to wind. Again, landing grounds ashore might be bad or even non-existent. These considerations might necessitate the use of seaplanes, providing another example of the value of seaplanes and their carrying-ship under certain circumstances. Further difficulties are imposed by the great variety of work required, such as spotting for naval or military guns, fighting, contact work, and naval or military reconnaissance.

The great vulnerability of the beaches to low-flying aircraft, and of the large numbers of anchored transports to attack by torpedo aeroplanes, must not be overlooked.

Generally speaking, the introduction of aircraft into "combined operations" appears to favour the defender more than the attacker, as the latter's machines will probably have to work from ships, or extemporized bases, and whilst suffering from the inevitable disadvantages which such conditions impose, will have to carry out complicated, varied and difficult flying.

## **Chapter IV**

### **The Possible Future of the Various Types of Aircraft**

A forecast of the future of the various types of aircraft can only be attempted after duly weighing the various governing factors of the problem. There appear to be three factors: First, the limitations of the various types; second, the probable requirements in another war against a first-class naval power; and finally, the teachings of the late War, many of which have already been dealt with in previous chapters. On the above lines the problem will now be considered.

*Limitations of Machines Heavier-than-Air and Lighter-than-Air.* The way in which machines are likely to develop in the future appears to be determined by certain mechanical facts. If heavier-than-air be considered first, the farthest that an aeroplane or seaplane can fly in still air, taking a reasonable load of bombs, guns, etc, is, to-day, about 400 miles. Now this is not improved by increasing the size of the aeroplane, because in practice the bigger the aeroplane the greater is the structural weight compared to the useful load carried; and also because the spreading of weights over the structure, which seems necessary with increase of size, causes heavy stresses when alighting. Hence, in the future aeroplanes and seaplanes appear to be limited to flights of about 400 to 600 miles, and the average speed at which they fly is at present about 110 mph. (Attention is drawn to the fact that, as explained in the Introduction, "the future", unless specially stated, refers to the next ten years).

Improvements in the motor, in constructional methods, in propellers, will doubtless cause greater efficiency, but as these are likely to be gradual improvements and not fundamental changes, the limit suggested above seems reasonable.

With the airships the conditions are different. If the ship is increased in all its dimensions in the same proportion, the volume increases as the cube, and the surface as the square, therefore to drive it at the same speed requires relatively less power. This advantage is not all lost through the fact that the stresses on each circular sector increase with the diameter. Generally speaking, then, the bigger the airship the more efficient it is, and the limits which are met first are the size of the shed, or the difficulty of mooring out a really large ship. Notwithstanding these limits, the present-day airship is capable of carrying a reasonable fighting load a distance of about 1,500 miles in still air at a speed of about 60 mph. In the future, then, the use of the airship is for flights beyond the limits of heavier-than-air machines, accomplished at a more moderate speed and with a bigger load.

The extreme vulnerability of the airship to attack by a high performance aeroplane is another limit. At present it precludes the use of airships from localities where enemy fighters are strong, and the writer considers that probably this will remain the case in the future. The question of defensively arming the big airships demands very careful investigation, also the question of airships fighting each other.

*Probable Requirements in a Future War Against a First-Class Naval Power.* Having defined the fundamental limits of the two main classes of aircraft it is appropriate next to consider whether the requirements of a future war against a first-class naval Power are likely to differ from the late War.

A little reflection leads to the conclusion that we are most unlikely to find ourselves placed in so favourable a strategic position as in the late War, with the British Isles situated across the arteries of the sea communications of our enemy.

Again, in the late War the main bases of the opposing Fleets were separated only by some 500 or 600 miles. Is this likely to occur again? On the contrary, it is far more probable that this distance will be greatly extended, and the key of the naval situation instead of being the control of the North Sea may be the control of a great ocean. Or it is possible that the enemy's fleet may be so distant that before naval operations on a large scale can begin, our Fleet will have to move to bases situated nearer the enemy, whilst our trade and possessions within striking distance of the enemy's fleet are protected as much as possible in the meantime by local resources.

Another consideration is that the increasing use of aircraft in naval warfare will have the effect of forcing fleets to move at night or under water if they are to be unobserved, in the same manner as troop movements are nowadays made in darkness, or with great attention paid to concealment and camouflage.

What, then, are the inferences to be drawn from the difference between the probable requirements of the future and those of the late War? Obviously we cannot be content with ranges and performances which would have suited the North Sea. There must be no slackening of effort to produce aircraft with greater radius of action, greater speed, and greater all-round efficiency. Night flying and anti-submarine work must continue to be developed. Also the possibility of the Admiralty calling upon the Independent Air Force to endeavour to secure aerial supremacy over a specified part of the ocean during any big fleet movement should be recognized. The possibility referred to above of distant possessions and maritime trade being protected by local resources pending the arrival of our Fleet (which would probably take several months) opens up great possibilities for aircraft. Aircraft would be invaluable as part of these local resources – their use in defence against invasion has been emphasized in Chapter III.

The rapidity with which aeroplanes can get to Australia forms a striking contrast to the time it would take our Fleet to reach the Pacific should its presence there be necessary. When once the Empire's air routes are developed, a powerful air force from some central position such as Egypt, could be sent to any threatened possession long before the Fleet could arrive.

If imagination is allowed to take us somewhat beyond the ten years by which the writer defines "the future" for the purpose of this paper, it is not difficult to visualize the Air Force undertaking some of the present functions of the Fleet, transporting expeditions to enemy countries by air, arriving rapidly to reinforce beleaguered garrisons, or fighting a campaign against merchant shipping with large numbers of torpedo-carrying aircraft. Indeed, the imagination leads us into a veritable Abdullah's Cave of strategical possibilities. We are led, perhaps, out of the scope of this paper – co-operation with the Navy – into the sphere of independent air strategy. But in an age when the rapidity of communications and transportation continues to increase, a contemporary speeding up of warfare is inevitable, and such possibilities for the more distant future must be recognized. By recognizing them

we can ensure that aerial development in the immediate future, and the development of imperial strategy, progress along lines which will eventually enable air power to be a safeguard to the Empire.

To return, however, to the question under consideration. Another point which should be borne in mind before trying to predict the future uses of aircraft, is that in the late War machines designed for work with the Army were produced in much greater numbers than those for the Navy. Therefore, it was often good policy to adapt a primarily military machine to naval use, because only by reducing the number of types could sufficient production be maintained. But in the next War the opposite might be the case, and therefore in peace time the provision of makeshift machines for naval purposes should be avoided.

Subject to the various considerations enumerated in this Chapter, some prediction of the future of the various types of aircraft for sea reconnaissance and co-operation with the Navy will now be attempted, and aircraft from ships at sea will be dealt with first.

*Aircraft in Fighting Ships.* In a modern Fleet the writer considers there should be special aircraft-carriers and also aircraft in certain fighting ships.

Each light cruiser should carry a machine, either a single-seater fighter or a two-seater reconnaissance machine, so allotted that there was one of each type in each pair of light cruisers. The role of the fighters would, of course, be keeping down all enemy machines. The reconnaissance machine was not part of our Grand Fleet programme during the War, but as so much of a light cruiser's work is reconnaissance there can be little question that they would be most valuable, and it should be possible in the future to produce a suitable two-seater for this work. Wireless telephony will probably prove a most useful means of communicating with reconnaissance machines, and also with spotters.

As regards the battleships and battle cruisers. Each, it is thought, should carry at least one two seater for spotting and at least one fighter. This would ensure that each squadron of ships had its own quota of spotting planes and fighters to protect them. Also it would avoid the complications and the anxiety to the flag officer commanding the squadron which there would be, if machines from a special aircraft carrier accompanying the squadron carried out these duties. In future it may be possible to produce a three-seater for spotting; if so, it would be a great advantage to have a gunner in addition to the pilot and observer. The author considers that spotting, and reporting enemy movements in a naval action is too difficult for the pilot alone to do, and this necessitates the passenger (if only one is carried) being primarily an observer.

*Aircraft in Carriers.* Now as regards the aircraft carriers. It is impossible to lay down any definite proportion of these to the other classes of ships, since this must depend on the composition of the adversary's fleet and the nature of the battle it is expected to fight. But it is possible

to predict the types of machines to be used from the carriers. These ships should work directly under the Commander-in-Chief (except, perhaps, one or two under the flag officer commanding the most advanced light cruisers or battle cruisers), and should be stationed within visual signalling distance of him, if possible. They should carry fighters to enable aerial supremacy to be obtained at any given time and over any particular area should the Commander-in-Chief wish it; also torpedo machines, bombers and reconnaissance machines, all working directly under the C-in-C. It is quite clear that this will necessitate there being a considerable number of aircraft carriers in a modern fleet, and that the number of carriers should be greater in proportion to the surface craft than was the case in the Grand Fleet in the late War.

Another use for the fighters will be low-flying attacks on ships, particularly destroyers whose personnel is so exposed. A determined low-flying attack on a flotilla by a squadron of fighters might easily prevent a destroyer attack being pressed home.

The carriers generally should be large ships, but a certain number of small ones (probably without landing-on decks) will be necessary for operations with light forces, like the Harwich Force in the War. Apart from the value of carriers in a fleet action, they will be useful for minor offensive operations against objectives which are beyond the reach of aircraft from shore bases.

Then there is the question of whether the machines carried in fighting ships and in carriers should be aeroplanes, or seaplanes with wheels for flying-off and capable of being dropped. The author considers that if seaplanes can be produced to fulfil the necessary flying-off conditions from the fighting ships, and in addition the necessary alighting conditions in the carriers, and also have the required performance in the air, they should be used. Obviously the fighters must be aeroplanes, but in the future the spotting machines and perhaps those for reconnaissance might be seaplanes. With the seaplanes the strain on the personnel and the wastage would be much reduced. Also, wherever the Fleet went in peace time the machines could make daily practice flights, weather permitting, irrespective of whether there was an aerodrome near by or not, and of whether the Fleet was at sea or in harbour. There will also be special uses for seaplanes from seaplane-carriers, in combined operations and minor operations, as explained in Chapter III.

*Aircraft from Shore Bases.* From shore bases the future of the airship is to work beyond the range of heavier-than-air machines, or in localities where hostile fighters are weak or neutralized. Fleet reconnaissance, patrols, anti-submarine work, bombing and reconnaissance of enemy ports, and perhaps mine-laying will all be part of the airship's duties under these conditions.

The same duties will be carried out at shorter ranges by heavier-than-air machines. Here, again, the question of seaplane or aeroplane arises, and the answer, the writer considers, is the same,



viz, where the performance which is required permits, use a large flying-boat if a big machine is wanted, or a seaplane (fitted with wheels and flown off an aerodrome if sheltered water is not available) if a smaller machine is wanted. The writer considers that small flying-boats have no future, as experience has proved that they are easily swamped.

But if the employment necessitates a very high performance an aeroplane must be used; for instance, the amphibian suggested (see C, page 248) would be suitable for anti-submarine work if there was little opposition, although for similar work or reconnaissance on a strongly-defended hostile coast, everything else should be sacrificed to performance, and an aeroplane used.

In addition to the duties enumerated, heavier-than-air machines would be most valuable for attacks against an attempted landing, as already explained. In such operations, and for attacks on ships in harbour the torpedo machine has a great future. These machines should be developed on two lines, the small handy machines (particularly suitable for work from ships) to attack at close range, and large machines for attack at longer ranges, requiring less manoeuvrability. For the latter work the flying-boat is believed to have already been found suitable. With the advent of the improved mooring-out capabilities suggested (see D, page 248), it is easy to visualize a squadron of torpedo-carrying flying-boats working like a destroyer flotilla of today.

In all aspects of overseas flying the difficulty and importance of accurate navigation is very great. Too much attention cannot be given to this question. At present directional wireless seems the most promising method.

*Conclusion.* Finally, it is only necessary to add that whereas in the late War aircraft gradually became valuable in nearly every branch of naval warfare, study leads to the conclusion that in the next war against a first-class naval Power the use of aircraft will be very greatly extended. Consequently, to a naval Power which now develops aerial co-operation with the fleet, largely and on sound lines, aircraft are a vast accession of strength. But to a nation which fails to do this they are a most serious danger.

## Commander's Perspective

# Establishing the Air Truth

By Air Marshal (Retd) Sir Stuart Atha KBE CB DSO RAF

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**Biography:** Air Marshal Sir Stuart Atha KBE CB DSO retired as Deputy Commander Operations at Headquarters Air Command in May 2019. During a distinguished career, Sir Stuart led No. 3 Squadron during Operation Telic 1, commanded RAF Coningsby, was Officer Commanding No. 83 Air Expeditionary Air Group, Air Officer Commanding No. 1 Group, Air Component Commander for security during the 2012 London Olympics and Chief of Staff (Operations) at the Permanent Joint Headquarters, Northwood.

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*A retrospective review of post-modern air power application; alternatively, what my career has taught me about air power.*

*Truth is the property of no individual but is the treasure of all men.*

Ralph Waldo Emerson

## Introduction

**A**ny retrospective harvest of a career for lessons runs the risk of exaggeration, self-promotion and the partial selection of events to wrap prejudices in the cloak of illusory truth. Inevitably opinions are based on an eclectic mix of experiences and, whilst I claim to be alive to these risks, I accept that readers (especially those who know me) may hear the faint clippety-clop sound of the occasional hobby horse. There are rarely ground truths, merely perspectives; it is a truism that where you stand on any issue depends on where you sit. I have endeavoured, however, to guard against the inappropriate extrapolation of an anecdote to some universal truth; instead my aim is to establish some home truths relevant to those interested in the effective application of air power. These truths are not extensive, are based on *my* experience, and therefore are my air truths.

Despite the reaffirming experience of our centennial celebrations, I still sense in Air Force circles the whiff of under-confidence, which is, perhaps, rooted in our status as the 'junior Service'. Knowing something of the small man's complex, I realise that we younger siblings can be quick to take offence, and too readily adopt a defensive crouch whilst forwarding arguments that sound shrill and singular to others. There is no need for this. A cursory review of the Royal Air Force's distinguished record over the past century – and notably in this post-Cold War era – should encourage us to stand tall, speak air truths unto power, and move forward into our second century with confidence and optimism.

The caricature continues with the description of airmen and airwomen as 'doers' not 'thinkers', who leave doctrine writing and reading to the air power zealots. When they do write, they like to use small words, simple ideas and PowerPoint slides. Intellect is necessary but intellectuals are discouraged. Decision making is intuitive rather than considered and involves the rapid assimilation of risk and benefit. Whilst I recognise some of this in the person staring back at me in the mirror, this article is an attempt to address these perceptions and to underline my belief in the importance of 'Thinking, and writing, to Win'.

My task is, therefore, to search the operational lie of the land, spatially and temporally, for air truths. The landscape surveyed is a career of service on operations, abroad and at home, that coincides with the post-modern era of air power. What follows are my perspectives – my *truths*, if you like – based on the view I have had from privileged seats in the cockpit, the Combined Air Operations Centre (CAOC) and the UK Government's Cabinet Office Briefing Room. The 'truths' are not the 'top ten' of air power issues and they are not the sole preserve of air forces. Nor, however, are they the idle musings of a detached observer (or, worst of all, an

‘armchair air marshal’), but instead the reflections of an airman who has had the great fortune to be part of an air force that is respected, valued and has been employed on operations – at home and abroad – throughout his service; an airman who is proud to have played a part in a range of operations with this nation’s, and many other nations’ finest, in the air, on the land and at sea.

As is befitting a child of decimalisation and someone attracted by symmetry, I have identified the following 10 air truths.

- 1. Air forces are at their most potent when integrated to the joint force.***
- 2. The effective delivery of air power and a considered political strategy are mutually dependent.***
- 3. ‘Air power is the most difficult of all forms of military force to measure, or even express in precise terms.’<sup>1</sup>***
- 4. Air forces risk being tactically excellent and operationally absent.***
- 5. Air Forces need to remain adaptable; the operation you will fight in is probably not the operation for which you prepared.***
- 6. A powerful and symbiotic relationship exists between air forces and special forces.***
- 7. Network Enabled Warfare is not new and is essential to the effective delivery of air power.***
- 8. The rapid delivery of understanding in the battle space is a unique strength of air (and space) forces, but ambiguity will continue to challenge decision makers.***
- 9. The future success of air forces depends on transforming how we train.***
- 10. Day 1 is the most dangerous day of any operation.***

***My First Air Truth: Air forces are at their most potent when integrated to the joint force.***

The British politician and statesman the late Lord ‘Paddy’ Ashdown often said that the armed forces were at their best when they worked together, a condition dependent on mutual trust and respect, the tolerance and celebration of differences and similarities, whether in MOD meetings or on Middle East operations. Yet there remains unhealthy conflict between the Services in a competition where no one wins, this despite the importance of teamwork being instilled at Cranwell, Dartmouth and Sandhurst, where virtuous collaboration is promoted,

and toxic parochialism discouraged. Tribalism is perhaps inevitable in any organisation that sets such great store by team and identity, where there is a constant fight for resources in an era of enduring financial pressures, and have distinct environments within which the Services operate and employ technology. The operational imperative, however, demands joint teams drawn from across the Services, expert men and women proud of their disparate identities but working as one to a common goal. We still have some way to go before all three Services operate individually and together with equal ease, confident of their place within the order of battle. The challenge is to create, foster and promote a joint instinct, a joint identity, whilst protecting the ethos and culture of the individual Services.

## **Purple Reigns**

'Purple' (that is to say 'Jointery') became the 'new black' for the UK's armed forces in the 1990s and encouraged by the 1998 Strategic Defence Review (SDR). Great progress was made with the establishment of a myriad of joint organisations, including the Permanent Joint Headquarters (PJHQ), the Joint Services Command and Staff College, and front-line formations such as the Joint Helicopter Command and Joint Force Harrier. The subsequent experience would suggest that joint institutions are at their most effective when sitting above the Services, like PJHQ, or astride the boundaries between them, like the JHC. More recently, Joint Forces Command (JFC) has acted as the UK Armed Forces joint focal point, although, thus far, it has been more of an under-resourced purple orphanage than an empowered joint director and co-ordinator. The imminent rebirth of JFC as Strategic Command in December 2019 may provide the much-needed impetus to transition from single-Service sibling to an integrator with genuine authority, where the combined attributes of the single Services are synergised; in short, where Defence comes together to deliver.

## **PJHQ**

Regardless of the shortcomings of its superior formation (the JFC), PJHQ is, and must remain, the exemplar of operational jointery. The counter-insurgency operations of Iraq and Afghanistan have dominated in terms of blood and treasure expended, and the excessive emphasis placed on land forces has put at risk PJHQ's joint credentials. The operational experience of the UK Armed Forces in the post-modern era, however, is much more diverse, underlining the need to insure against the risk of parochialism and bias. In addition to a steady stream of Humanitarian Relief operations, unexpected operations in the post-Cold War era have arisen with Olympic periodicity. The operations in 1991 (Iraq), 1995 (Bosnia), 1999 (Kosovo), 2003 (Iraq), 2007 (Russian Long-Range Aviation sorties recommenced), 2011 (Libya), and 2015 (Iraq/Syria) have each underlined the central importance of a joint operational-level headquarters, able to integrate single-Service tactical activity, cohere the UK's contribution with partners and coalitions, and act as the bridge to, and sometimes a firewall from, Whitehall.

## **Homeland Operations**

There remains a gap, however, in the direction of homeland operations. Whilst the Army can lead the response to bovine diseases and national strikes, they are not well equipped to

coordinate, let alone integrate, air, maritime and land activity in the UK. The success of the UK Armed Forces' contribution to delivering a safe and secure London Olympics can be attributed to the innate jointness of the commander, General Sir Nick Parker, and despite the lack of PJHQ involvement. The 2012 Olympics also demonstrated the importance of greater integration of the military and other cross-Government entities, reinforcing the need for a Comprehensive Approach, Fusion Doctrine or whatever the in-vogue description of joined-up government is today.

## Carrier Aviation

The Falklands Conflict in 1982 provides a rich seam for joint lessons, both good and bad, relevant to the employment of aircraft carriers. The sense of a joint team was in short supply at sea, which contrasted with the integrated efforts delivered ashore, where the demands of mortal combat displaced any room for single-Service tribalism, as it always does.<sup>2</sup> The unfortunate experience on board HMS Hermes highlights the importance of the tone set by the captain. Fortunately, the RAF squadron commander, Wing Commander Peter Squire, employed all his skills of tact and diplomacy on board HMS Hermes to mitigate the damaging consequences of the toxic atmosphere. One of the lessons of carrier aviation in 1982 was that when trust is lost, we all lose. **It does not need to be this way**, as demonstrated by the highly successful carrier deployment to the Gulf in 1998. This involved HMS Illustrious and an RAF Harrier Squadron deployed in support of Op Bolton, the UK's contribution to policing the Iraqi Southern No-Fly Zone. The RN and RAF contingents worked harmoniously together thanks to the sense of team instilled by the Captain and the Squadron Commander. I enjoyed a similarly productive deployment on board HMS Illustrious in 2001, again this was because of the generous and collegiate nature of the Captain (Capt Charles Style on this occasion).



Aircraft Landing on HMS Illustrious.



F-35 First Landing on board HMS Queen Elizabeth.

UK Carrier Strike, the combination of the F-35 Lightning and the Queen Elizabeth Class aircraft carrier, is a potent symbol of national ambition and offers the Government a paradigm shift in power projection. To realise this potential, we must recognise and exploit the strengths that sit at the heart of both the Royal Navy (RN) and the RAF, whilst respecting the traditions and practices of each Service. Senior RN and RAF officers must, therefore, dump all tribal baggage, ignore the siren calls of ancient mariners and airmen alike, and ensure that the first operational

deployment of 617 Squadron F-35 Lightnings on board HMS Queen Elizabeth (and alongside the USMC) is planned and conducted as partners and in a spirit of openness and collaboration. You only have one chance to make a good first impression on partners, politicians and the public.

***My Second Air Truth: The effective delivery of air power and a considered political strategy are mutually dependent.***

Whatever one's view of Britain's place in the world, there was global astonishment at the level of ambition and commitment displayed by the UK in 1982. The combination of political rhetoric and the Task Force sailing towards the South Atlantic remains one of the most potent expressions of political intent. It was also a profound demonstration of the physical and cognitive effects deliverable by the Carrier Strike capability. The post-Cold War era has been characterised by so called 'wars of choice' that present more challenging political intervention dilemmas. Consequently, the sensitive and sophisticated relationship between the political intent of governments and the application of military force has dominated the discourse on intervention, both in public and parliament. Moreover, the debates and parliamentary votes in March 2003 (invasion of Iraq), August 2013 (air strikes against Assad regime targets in Syria) and December 2015 (air strikes against ISIS in Syria) have further complicated both the sufficiency of evidence and the authority of governments to go to war. Whilst conflict and controversy appear to be two sides of the same air operational coin, the truth is that air power has proven to be a versatile military force that can be interwoven with diplomacy and calibrated to match political ambition and risk appetite, offering governments a wide range of choices when grappling with intervention dilemmas.

## **NATO Over Bosnia**

NATO's Operation Deliberate Force, the first combat operation conducted by the Alliance, was characterised by the sophisticated integration of diplomacy and air power over a 3-week period in 1995. Precise and discriminate air power was applied and withheld in concert with political dialogue supporting a strategy that was more 'Talk and Act' than 'Shock and Awe'. Diplomats offered the carrot, whilst NATO's air forces wielded the stick in a strictly calibrated manner synchronised with the diplomatic campaign. This way in war proved popular with the western democracies of the Alliance and was preferred to the blunter approach of taking and holding ground. It proved successful, leading to the Dayton Accords and the end of the war in Bosnia – without any NATO fatalities.

## **NATO Over Kosovo and Serbia**

Four years later, Operation Allied Force, NATO's response to Slobodan Milosevic's persecution of ethnic Albanians in Kosovo, yet again demonstrated how well air power, diplomatic pressure and strategic communications can be integrated. The 78-day campaign involved the diverse use of air power, ranging from tactical attacks in Kosovo to strategic strikes into Serbia, synchronised with a belated but effective strategic communication effort. The Alastair

Campbell diaries covering this era provide an interesting perspective on this<sup>3</sup> and illustrate well the importance of integrating the application of air power with both media and information operations as part of an Information Strategy, which is in turn guided by carefully considered political objectives. This was not the case at the start of the operations but improved through the campaign thanks to Campbell and others. The delivery of lethal and destructive force from the air over the 3-month operation amplified the message to Milosevic of NATO's unity and political resolve, helped by reassuring strategic messages to domestic audiences, emphasising the application of discriminate and proportionate qualities of air power, despite the occasional mishap such as the accidental bombing of the Chinese embassy in Belgrade. The overall effectiveness of NATO action is returned to later.

## **NATO Over Libya**

In 2011, Gaddafi's brutal repression of the Arab Spring uprising in Libya presented western governments with a difficult test of their resolve to support the UN Responsibility to Protect principles with action as mandated by UN Security Council Resolution 1973. The intervention decision focused on how, not if, to intervene and was complicated by the US reluctance to lead the effort and the absence of a dominant line of diplomatic activity with which NATO military force could be integrated. The use of air and maritime forces, which did not mire the Alliance in a 'boots on the ground deployment', combined with the ability to operate beyond the range of hostile systems, increased their attractiveness to the international community (who were suspicious of western political motives); to NATO countries' domestic audiences (who were sensitive to any operation that might involve casualties and enduring commitment); and to our national political leaders (who could be seen to act decisively in a way that lent itself to political *control* with arguably limited political *risk*). Moreover, the limited ground footprint in Libya made extraction from operations relatively simple, when compared with the 'land-centric' deployments to Iraq or Afghanistan. From the outset, NATO made it clear that it was only responsible for the military line of operation, protecting civilians and implementing the arms embargo and No Fly Zone, thus hindering the integration and synchronization of military action with a range of activity including diplomatic and economic levers. The events in Libya 2011 are a valuable source of lessons for both governments and militaries and provide critical insights into intervention decisions and how nations discharge their Responsibility to Protect. Whilst 'warfighting at scale' – as required by a NATO Article V-type operation – has the serious potential to lead to the end of the world as we know it, the political decision to participate in such an operation is arguably simpler than in the case of a highly politicised decision to participate in war of choice. Such decisions are difficult and need to be supported by a well thought through strategy rather than a knee-jerk response to events and the public clamour for action. As events in Syria demonstrate, however, the consequences of deciding *not* to act can have ramifications that are just as dangerous as deciding *to* act.

## **Number 11 Group**

The RAF's re-formation of Number 11 Group in 2018 marked a step change in the RAF's ambition to conduct operations across all domains and to integrate tactical activity with



information operations. The 11 Group three pillars of Operations, Space and Information Advantage may be crudely drawn at present, but they will provide the basic architecture on which information-centric campaigns will be built in the future and should ensure our activity is better synchronised horizontally with the other Services and vertically with PJHQ and other Government and international actors. The pathfinder 11 Group operation for this ambition was the small-scale 2018 NATO Air Policing deployment of a Typhoon squadron to Romania on Op Biloxi. A sophisticated Information Operation drove the Typhoon flying programme over the Black Sea (rather than the more commonly applied inverse of that approach), with the aim of communicating messages tailored to a range of audiences, including the Russians and the Romanians. The 2019 deployment to the Baltic Region on Op Azotize built further on this and strengthened the links with the British Army's 77th Brigade<sup>4</sup> and PJHQ. The assessment of air operations is dealt with elsewhere, but on this occasion, measuring the success or otherwise of the efforts to reassure NATO partners and deter Russia was as difficult as it is critical. After all, you usually only know for sure when deterrence fails, not when it works. We do know, however, that the stand-up of 11 Group will help enhance the RAF's ability to play its part in coherently and effectively amplifying political and diplomatic messaging.

***The Third Air Truth: 'Air power is the most difficult of all forms of military force to measure, or even express in precise terms.'***

My Third Air Truth has been borrowed from Sir Winston Churchill and is as true today as it was when Portal and Harris were planning and directing the Strategic Bombing Campaign in World War II. Any high-performing organisation needs to know its numbers, to know those measurable factors which are critical to an informed assessment of success or failure. In recent years, it has been fashionable in staff colleges and elsewhere to worship the 'art' of war rather than its 'science'. There have been good reasons for this (not least in the UK due to its inconsistent grasp of the operational level of war, and the art required to direct it), but in this context it has been an enduring challenge for air forces to quantify and articulate their campaign value. Finding the magical metric that is easily measured and directly linked to operational success has been the holy grail for air commanders throughout the 'air century', and it has been even more difficult, as Churchill asserted, to express that contribution to non-airmen who are apt to relegating air power's vital contribution to just that of the supporting cast.

## **Operation Allied Force - Air Power Effectiveness in Kosovo and Serbia**

NATO's Operation Allied Force in 1999 was for some the highwater mark of air power in the post-modern era and claimed as the most successful air 'campaign' ever. 'A turning point in the history of warfare,' wrote the respected military historian Sir John Keegan, proof positive that 'A war can be won by airpower alone.'<sup>5</sup> In the Pentagon, the Chairman of the Joint Chiefs of Staff, General Henry Shelton, claimed that NATO's air forces had destroyed around 120 tanks, 220 armoured personnel carriers and up to 450 artillery and mortar pieces. However, when

the US Munitions Effectiveness and Analysis Team (MEAT) deployed to Kosovo, they found these claims to be grossly exaggerated. The issue of the number of 'tanks' destroyed therefore became a favoured measure by which to gauge the success or otherwise of air operations, an approach eagerly championed by those who were tired of a decade of airmen cockily proclaiming that 'Armies occupy, Air Forces conquer'.

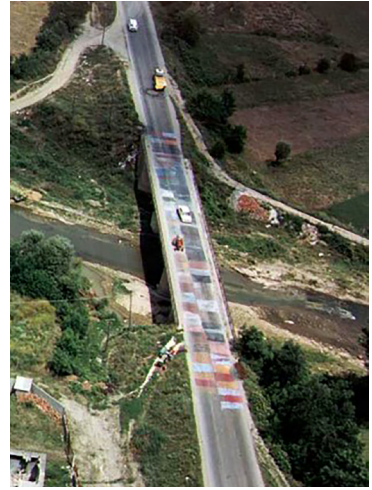
So how relevant was the apparent 'failure' of air power to destroy the Serbian war machine, as imagined by those with a tank fixation? George Robertson, the UK's Defence Secretary during the operation and one year later speaking as Secretary General of NATO, perceptively responded 'Enough', when asked how many tanks had been destroyed.<sup>6</sup> He went on further to say that, 'The aim was not to wage war against Yugoslavia or to bring about the fall of Milosevic and his regime. The air campaign set out to disrupt the violence against the Kosovars and to weaken Serb military capabilities in a carefully controlled way. And that is what we did'.<sup>7</sup>

### **The RAF Weapons Effectiveness Team**

It is sometimes forgotten that the RAF deployed its own equivalent of the MEAT, comprising scientists, engineers and me. I opted to call our team the Weapons Effectiveness Team or 'WET'; whimsically named, but with a serious purpose. I had the unique experience of flying combat missions during Operation Allied Force and then returning on the ground when combat operations ceased to compare the view from above with the reality on the ground. Whilst the WET's focus was initially on assessing the physical effects of bombs on buildings, bunkers and bridges (as you might expect, we only found a couple of destroyed tanks), it was the surprising abundance of evidence of tactical cognitive effects that was of greatest interest. The popularity of NATO's action amongst Kosovan Albanians was widespread. Wherever the WET visited, we were quickly surrounded by large groups chanting support for NATO and Tony Blair. On one site, I met a Kosovan and his son who were rebuilding a house that a wayward UK bomb had destroyed. After showing him the aircraft video of the attack and explaining what had gone wrong, he said, 'Tell your friend, thank you. I have my health; I can rebuild the house and the Serbs have gone because of him'. On another occasion, a Kosovo Liberation Army fighter in Dakovica seemed strangely uninterested in the tank controversy. For him it didn't matter if the tanks and the armed personnel carriers were destroyed or hidden in the Pristina Bus Station; the Serbs were not using them because of the air threat and the disruption to movement inflicted by the bridge attacks. In the end, NATO's objectives were achieved; but it is a stretch to claim this for air power alone. Milosevic was coerced by a much more complex and sophisticated array of factors, of which 78 days of air operations were critical, but just a part. The debates during the operation, which can be characterised by the tactical air power focus of SACEUR (General Clarke) versus the more strategic application preferred by the Air Commander (General Short), combined with the debates after the operation, underline the challenge of establishing the ground truth and measuring air effect in such campaigns.

## Concealment and Deception

Part of the reason for the disparity between the number of targets claimed versus the number destroyed, was the extensive use of decoys by Serb forces. Olive-coloured filing cabinets with plastic pipes and car wheels rested against them, looked very much like artillery from a couple of hundred yards, let alone 3 miles (the height of NATO aircraft). The Serbian deception measures ranged from the simplistic use of black polythene to create false roads and bridges for the Alliance to bomb, to the more sophisticated step of painting colourful squares on the surfaces of bridges to confuse the targeting systems within NATO weapons. The experience of Kosovo demonstrated that air systems are susceptible to concealment and deception measures.



This vulnerability reinforces the importance of fused technical and human intelligence to develop an understanding of the situation on the ground, a subject I will return to when considering the symbiotic relationship between air forces and special forces.

## Measuring Campaign Success

In Libya in 2011 it was again difficult to know if the operation was succeeding, stalling or failing. The position of the line between opposing forces and the amount of territory occupied by friendly forces were obvious and attractive measures of success (and easily determined by the RAF Sentinel sensor), which led to much talk of stalemate during the summer, when there was little movement of the battle lines. Metrics of success were also a contentious issue during the counter-Daesh operations in Iraq and Syria in 2015. Some US military leaders insisted on using enemy body count as the key metric, despite the difficulty of measurement or the experience of Afghanistan where the number of Taliban killed appeared to have little correlation with the success of the campaign. Consequently, PJHQ developed its own assessment of campaign progress as part of an overhaul of its campaign management. Many colourful charts were produced, measuring a variety of parameters and assessing them against campaign objectives. Whilst the charts provided a reasonable picture of the current situation, they were less useful in forecasting campaign progress and thus the future air power requirement.

## Measuring Cognitive and Physical Effect

The truth is that it is difficult to accurately measure campaign progress in general and the effects delivered by air power specifically, particularly where the objectives are cognitive rather than physical in nature. Air forces must guard against setting too much store by metrics that are appealing because they are easy to measure, like the number of sorties flown and amount of ordnance expended. Such an approach dogged USAF and US Navy operations in Vietnam, and drove a competition between the Services that had no bearing at all on the operational

effects they should have been delivering. Simple yardsticks do have some value in assessing simple matters, such as in weighing the balance of effort of contributing nations (10% of the US effort is considered appropriate for the UK) but commanders must beware unbalancing a campaign by giving a particular metric undue priority. In Afghanistan, there was a risk that the focus on Troops in Contact response times skewed the air tasking. Certainly, significant CAOC effort went into reducing the time taken, for good tactical reasons, but this gave rise to the mischievous suggestion that the CAOC Strategy Division was more of a 'Statistics Division'. Describing and assessing cognitive effects may always be more challenging than measuring physical effects, but the intelligent and effective application of air power depends on a deep understanding of both.

***My Fourth Air Truth: Air forces risk being tactically excellent and operationally absent.***

I accept the charge of exaggeration, but only just. There is no doubt that the RAF's current generation can be very proud of its performance; they are a team of outstanding men and women, military and civilian, who have done great things for their country at home and overseas, without seeking or receiving the spotlight of publicity they deserve. It has been my privilege to see persistent professionalism and the conduct of unselfish, brave and skilful acts in the air and on the ground. The application of force and, equally, the decisions to withhold force, have been made with consistently exceptional judgement. Set against our tactical excellence, however, it is disappointing to see the limited influence that airmen and airwomen have had on the conception, development and execution of campaigns. There are exceptions, but they are just that, exceptions.

## **US CAOCs**

Part of the problem is rooted in a similar struggle in the US. USAF CAOCs are powerful sources of air power wisdom, expertise and direction. However, as Air Marshal Sir Arthur Coningham learned in North Africa in World War II, air commanders need to be inside the same country if they are to be inside the theatre commander's mind. As a result, and despite the pervasiveness of air power in Afghanistan, it was too often an afterthought to the plan and not an integral element; what a respected RAF planner likened to 'putting your underpants on after your trousers'. There are many other factors that account for this unfortunate shortfall. It was a land-centric campaign that was an aggregate of task force operations, making it difficult for the CAOC staff in Al Udeid to find the appropriate point of influence in the planning process. Air Planners were at their most effective when supporting theatre-level operations, such as the presidential elections. It was unfortunate, therefore, that the Afghanistan command and control model was applied to the counter-Daesh effort in Iraq and Syria, despite the fundamentally different character of the operations.

Whilst senior US airmen valiantly advocated for at least one rotation of a Combined Joint Task Force HQ built on a USAF framework, the enduring construct continued to be based on rotating US Army Corps HQs. Undoubtedly many talented soldiers, sailors, marines and

airmen were employed in these operational HQs, and on occasion air power was employed intelligently, but the C2 construct spanning Iraq and Syria was not optimised for the effective integration of air forces into the campaign and must not be considered to be the template for future operations. Command structures must be tailored to their operational realities, not to some doctrinal idyll. After all, as Carl von Clausewitz reminds us, 'The first, the supreme, the most far-reaching act of judgment that the statesman and commander have to make is to establish by that test the kind of war on which they are embarking; neither mistaking it for, nor trying to turn it into, something that is alien to its nature.'<sup>8</sup> Regardless of the kind of war, or the nature of the operation, the lesson of history is that someone with an expert understanding of air power should be part of the planning team from the conception through to the delivery of the plan.

## **Thinking to Win**

The RAF needs to think differently, if it is to continue to win in the future. The RAF's re-formation of Number 11 Group was a good start, but it needs to be followed by even greater investment in thinking. Liberal use of phrases like multi-domain operations are unhelpful if the lexicon lacks intellectual underpinning. Reportedly, a senior government official bemoaned the absence of air generals, an anecdote that further emphasises the importance of the RAF's 'Thinking to Win' programme, a coherent and wide-ranging effort launched by a previous Chief of the Air Staff, Air Chief Marshal Sir Andrew Pulford, to reinvigorate the RAF's conceptual component. The aim was to address intellectual shortfalls by better harnessing the thinking capacity of the entire air force. Some of the programme has delivered: the RAF has a strategy, and the Commandant Air Warfare Centre (AWC), the Director of Defence Studies and station commanders have done much to reinvigorate interest in the application of air power. But we are still dependent on the US and the French to provide C2 courses and our training for senior air commanders tends to the ad hoc and the bespoke. Much more is required if we are to ensure that the RAF's intellectual edge remains a competitive advantage and the excellence delivered at the tactical level is matched by presence and performance at the operational level.

## **Investing in Air Command and Control**

The primary way to increase our operational influence is to place 'Air Command and Control' (Air C2) at the front and centre of our thinking and not treat it as an auxiliary capability that plays second fiddle to our airborne platforms. Air C2 must sit alongside Attack, Control of the Air, ISTAR and Air Mobility as one of the RAF's key roles. Through continuing development, 11 Group and the JFAC are making positive strides to optimise the ability at home and overseas to direct operations in the air, space and cyber domains, while enabling those in the land and maritime domains. This progress must continue. The RAF's peacetime and crisis establishments need to better reflect policy ambition and ensure it has the resilience to support the many external calls on manpower both nationally and by NATO. Furthermore, no longer should the RAF follow a magic 'pixie-dust' strategy that relies on the salami slicing of the front-line to deliver individual augmentees to deployed operations; the RAF needs a

considered, articulated and credible manpower plan, involving the Whole Force, that delivers appropriately prepared men and women in the numbers required, without denuding the generating force at home of the vital manpower and skills it needs. Robbing Peter to pay Paul is not a sustainable strategy.

## **NATO Article V Operations**

The RAF needs to better understand how a 21st Century NATO Article V operation might be fought and how best to train for this. It must engage the RN at all levels and support both the Continuous At Sea Deterrent and Carrier Strike capabilities with an enthusiastic spirit of collaboration. The importance of operations across the hitherto neglected air-maritime seam is underlined by the arrival in service of both the F-35 Lightning and the P-8 Poseidon. Moreover, we must not think we have air-land operations hacked. In Afghanistan and Iraq, airmen and airwomen were humbled by the exceptional bravery of those on the ground and did their utmost to provide them with the intimate and persistent overwatch, protection, information and mobility they needed. But the brilliance of the UK armed forces' combined efforts in Afghanistan, Iraq and Syria should not blind us to the much greater challenges of supporting a manoeuvring division in continental Europe in an Article V-type operation. Neither the Army nor the RAF, nor indeed any of our NATO partners understand what this requires or how they are going to gain this understanding.

## **Adaptive Basing**

The RAF's thinking must not focus simply on what it does in the air, but must also address how and where it would operate from in time of war. Russia and other potential adversaries are enhancing their space-based Intelligence Surveillance and Reconnaissance (ISR) capabilities and are swiftly developing long-range air and surface-launched weapons (including hypersonic ones). No longer, therefore, should the UK be considered to be a sanctuary remote from the dangers of modern warfare. Depending on the scenario, our aircraft carriers provide a flexible basing option, but only for a proportion of the F-35 Lightning Force. The RAF needs to develop an adaptive basing concept that provides greater resilience through dispersal. Wherever the RAF operates from, it needs to configure Expeditionary Air Wings to better address the myriad of logistical, communication, mission support and force protection challenges associated with adaptive basing. An intrinsic element of this challenge is to develop ways that enable dispersed operations in the UK and overseas, supported by robust, flexible and credible doctrine.

## **Maintaining the Intellectual Edge**

Lastly, the RAF needs air power ambassadors and advocates, not zealots, who know how to wield air power as a coercive and deterrent tool, not just a destructive one. It must create the environment that fosters debate and engagement throughout our organisation. The AWC-sponsored annual Weapons and Tactics Conference was shamelessly plagiarised from the USAF and stands as an exemplar of this. The RAF must promote study and education (and promote in rank those who excel) to deepen the intellectual well from which to draw and

make best use of our talent and harvest good ideas, whatever the source. The technical developments of Typhoon and the arrival of the game-changing F-35 Lightning demands we lead technology with our thinking. Blind faith in advanced technology dulls the drive and desire for innovation and we will fail if we simply try to force these new capabilities into the old doctrine. We need to change our lexicon and drop irrelevant terms like fighter and bomber and embrace the challenges of the emerging operational paradigm that blurs the distinction between home and away, war and peace, physical and virtual, strategic and tactical. To succeed, doctrinal moulds may need to be smashed and sacred cows slaughtered. This requires people, whether they are in the cockpit, classroom or the CAOC, who are tactically excellent, competent in the art of campaigning, and who Think to Win. Only by doing so can we maintain the intellectual and therefore combat edge over our adversaries.

***My Fifth Air Truth: Air Forces need to remain adaptable; the operation you will fight in is probably not the operation for which you prepared.***

Time and again we learn that predicting the future is not one of our strengths. The UK's 2010 Strategic Defence and Security Review (SDSR) focussed on 'war amongst the people' and failed to predict the events of the Arab Spring, nor the return of a resurgent Russia and radical Islam in the guise of Daesh. Few expected Putin's annexation of Crimea, the nerve agent attack in Salisbury, or the associated crude cyber activity in the Hague. Even fewer predicted the drone threat that has emanated from Yemen, let alone the disruption caused by a series of alleged drone flights in the vicinity of Gatwick Airport in December 2018. So we should heed the wise counsel of the historian Sir Michael Howard, 'No matter how clearly one thinks, it is impossible to anticipate the character of future conflict. The key is not to be so far off the mark that it becomes impossible to adjust once that character is revealed.'<sup>9</sup>

## **The Cold War Legacy**

Throughout my early years, I was part of an Air Force that trained, equipped and postured for the Cold War scenario. Despite excursions like the Falklands Conflict, we had spent decades preparing for a particular fight. But when it came, the fight was not against the Soviet Red Army, but against Saddam Hussein's forces which had invaded Kuwait in 1990. 'Adapt and overcome' may have been the mantra we Brits employed, but some weapons like the JP233 runway cratering and area denial weapon were so designed that the scope for tactical innovation was extremely limited, and brave Tornado crews were forced to conduct low-level attacks at far greater risk than those who operated at much higher levels. It is to the credit of senior figures in the Jaguar Force that despite a suite of aircraft, weapons and tactics optimised for low-level operations, they rapidly adapted their tactics and operated from medium level. Later during air policing operations in Northern Iraq, the Harrier Force were using reconnaissance pods that were designed for low level, but had utility when employed using chinograph marks on canopies to aim them and flying knife-edge manoeuvres to employ the higher focal length cameras to produce images of useable resolution. Whilst such examples of tactical innovation were commendable, the speed of adaptation was slow, and



the RAF spent most of the 1990s evolving our equipment and tactics to catch up with the needs of the post-Cold War era.

## The Resurgence of State-Based Threats

More recent events in Libya, Crimea and Syria remind us that whilst we cannot afford to insure against all security risks, there is a requirement to maintain a broad spectrum of capabilities that can respond quickly to new and unexpected security threats. Unlike our adversaries of recent decades, we now face potential enemies which exhibit both great power ambition and pariah state behaviour; states whose ability to operate across the spectrum of conflict and in all warfighting domains continues to grow quicker than expected. The threats we face are advanced, comprising new advanced weapons systems as well as digital upgrades to legacy systems, such as the Cold War Tu-160 BLACKJACK (which has re-entered production) and the MiG-31 FOXHOUND (which is being used as the launch vehicle of hypersonic cruise missiles that are under development). Our speed of response will need to match their speed of upgrade.

## An Air of Complacency

Unlike the experience of recent operations, our potential adversaries are targeting our traditional strengths; they are not trying to outmanoeuvre us asymmetrically with low technologies; they are developing advanced 5th-generation aircraft and missile systems and are exporting them to other mal-intentioned states. The threat from the air is changing both to our deployed forces and to those at home as we see the proliferation of drones, cruise and ballistic missiles. The appearance of both the S400 surface-to-air missile and Su-57 fighter in Syria highlight this threat and underline the need to drop the expression 'near-peer' and instead simply refer to a 'peer' adversary. The relative freedoms we have enjoyed in the skies over Afghanistan and Iraq mean that awareness of the need, if necessary, to *fight* for control of the air has atrophied. As the former US Defense Secretary James Mattis warned, 'When our soldiers hear the noise of aircraft, they no longer look upwards, assuming the jet aircraft to be friendly; this will not always be the case'. The unqualified success of Western air power in recent decades means that complacency is the greatest risk to surface forces. No British serviceman or woman has been killed by enemy air action since the 1982 Falklands Conflict; and the last American soldier to be killed by enemy air action was in Korea. But the threats posed to us by our potential enemies are not idle: come the day, they can and *will* do us harm. As airmen and airwomen, we need to counter the complacent attitude that believes control of the air is a natural given state of affairs. We need to remind others that control of the air will yet again be violently contested and that its preservation is *a* (if not *the*) critical enabler of all our military endeavours. Taking control of the air is an air force's primary and enduring task: its loss spells defeat. As Field Marshal Erwin Rommel despairingly recognised, 'Anyone who has to fight, even with the most modern weapons, against an enemy in complete command of the air, fights like a savage against modern European troops, under the same handicaps and with the same chances of success.'<sup>10</sup> We must also recognise that space is an increasingly contested environment and that our growing dependency on space-based capabilities is increasing our



vulnerability and why, for the armed forces and air forces in particular, the sky must no longer be the limit to our interests. Control of space is of such importance to modern warfare that its loss, like control of the air, could have catastrophic consequences.

## **Reinvigorating the Conceptual Component**

The conceptual foundation of the UK's 2015 SDSR was based on the resurgence of persistent strategic competition and state-based threats. The policy response of 'warfighting at scale against a near peer threat in an Article V-type scenario' marked a quantum leap in Government ambition for the UK armed forces and a colossal shift of emphasis from the 'war amongst the people' theme of SDSR 2010. Whilst we respond to this challenge, the words of Sir Michael Howard above must resonate in our thinking and permeate our decision making. History teaches us that what we consider to be the most likely event is actually unlikely to happen because we take rigorous steps to deter that eventuality. Conversely, the threats that we either fail to spot or regard as unlikely, can creep up on us unawares because we have failed to deter them from occurring. Therefore, whilst we need capability optimised to the most dangerous threat described in SDSR 2015, we need equipment, doctrine, tactics and mindsets that are readily adaptable to a broad range of scenarios; to do otherwise would risk irrelevance. Central to our response is a reinvigorated conceptual component. To paraphrase Lieutenant General Sir Graeme Lamb, whilst we can train for the certain, we must educate for the uncertain. Delivering the 'Next Generation Air Force' exists much more profoundly in the conceptual than the technological sphere; although the RAF may be dependent on technology and armed with the most manoeuvrable aircraft we have ever operated, history teaches us that the key to success in the past, today, and in the future, lies in the conceptual component and the intellectual adeptness of our people.

### ***My Sixth Air Truth: A powerful and symbiotic relationship exists between air forces and special forces.***

The combined power of air forces and special forces is greater than the sum of the parts. Air forces provide special forces with firepower, mobility and an unblinking eye in the sky. Special Forces provide air forces with a persistent presence on the ground, generating unique insight and intelligence to help with targeting and building relationships with indigenous forces. Air forces and special forces possess complementary – not competing – strengths and, when interwoven, they are a force unmatched in terms of responsiveness, versatility and utility. Whether it involves a hostage rescue, elimination of key enemy leaders, interdiction of adversary supply lines, support to indigenous forces or an attack on heavily defended targets, air forces and special forces offer governments discrete, scalable and highly capable options.

## **Informing and Integrating**

Ignorance and integration are 2 key challenges for the combined air and special force. The need to protect special forces, their members, ways and equipment, promotes a

mystique that heightens the perception of omnipresence and overwhelming power. This can help when the audience is the enemy, but is a weakness when the ignorance extends into CAOCs and cockpits. Mutual trust, respect and understanding provides the critical underpinning to the relationship and requires significant investment of personal effort and time by both parties. Often both forces have capabilities that the other is unaware of or does not understand; the F-35 Lightning might stand as an air force example of this challenge. A liaison network that sits astride the boundary between the 2 forces, therefore, is critical. The special forces excel at building effective networks but there is a risk that the diminishing size of the RAF and our tendency to consider such C2 posts an overhead to be filled by random volunteers will erode our capacity to provide credible liaison officers in the right numbers, of the right calibre and character, and with the right skills.

Another challenge for the combined force is to integrate a highly sensitive national capability into the coalition, possibly comprising a wide array of nations from NATO and beyond. Ways have been developed within US CAOCs to put a firewall around this activity, alongside sensitive cyber and space capabilities, and to insert them into coalition campaigns. The experience of Libya in 2011, however, highlights the difficulties of developing similar processes within NATO. The most recent exercises involving the Standing Joint Force HQ and UK Joint Force Air Component suggest that whilst we are better prepared than we were, we still have some way to go.

## History Lessons

The classified nature of special operations fosters ambiguity and risks a diminished understanding of this critically important subject. Commanders need to study carefully, therefore, the classified lessons identified in this post-Cold War era. My first immersion in the combined force and the need to train and prepare rigorously together was the 1994/95 plan to extract British soldiers from the Gorazde enclave in Bosnia – a rare example of a sensitive operation that has subsequently emerged in public. The contingent operation required the development of a complex night-time heliborne extraction plan. Key to success would be the intimate synchronisation of Harriers, helicopters and forces on the ground. In preparation, a series of rehearsals were conducted covertly in both Wales and Scotland through 1994 and early 1995. Aircrew familiarised themselves with every nook and cranny of Gorazde, helped by the creation of a room which had 3D images of the town and surrounding terrain pinned to the walls. In the event, the plan was overtaken by the events of Op Deliberate Force and the Royal Welch Fusiliers simply drove out of Gorazde.

There are many instances of the RAF providing intimate support to ground forces, and readers should review the experience of Afghanistan in 2001, the Western Desert of Iraq in 2003, Libya in 2011 and Syria in 2016. As a former CDS, General Sir David Richards, said in 2011, notably 4 years before Op Shader, 'In an era when we are less likely to commit ground forces to combat unless our vital national interests are threatened, finding another means of achieving the same effect is vital'. The future relationship between proxy land forces and the air and

special forces who support them, therefore, will continue to be a crucial area for development, and further underlines the combined versatility and potency of air and special forces operating together.

***My Seventh Air Truth: Network Enabled Warfare is not new and is essential to the effective delivery of air power.***

Network-Enabled Warfighting is not a new concept and is the employment of Network-Enabled Capability to deliver operational tempo, enhanced situational awareness and therefore decision superiority and information advantage. From the early days of the RAF's formation, through every chapter of our history, including our 'finest hour' in 1940 and the London Olympics Air Security Plan of 2012, the RAF has built and exploited networks like the Dowding System to ensure the swift progression from understanding to decision to execution, integrating air platforms, processes and people with those of land and maritime forces, across the air, space and cyber domains, and with NATO and other coalition partners. As we consider the shape of the Next Generation Air Force and the future adversaries we may face, we must not let the complexity and array of multi-domain threats and technologies blind us to the simple principles of Network-Enabled Warfighting and the lessons of the past.

The RAF Strategy insures against this through the Strategic Objective that describes the ambition to become, *'An integrated Air Force that recognises information is its lifeblood, with people, processes and practices that allow it to respond rapidly and decisively to changing threats at all levels of warfare.'*<sup>11</sup> Satisfying this objective will require many strands of activity, including the training and education of our people in the ways of the information age rather than the industrial age. We must have adaptable structures and processes and platforms that can operate throughout the spectrum of conflict. This is a complex challenge requiring advances along the 3 principal axes of policy, technology and doctrine if we are to deliver a seamless war-fighting force that has the means to maintain persistent understanding and can rapidly decide and deliver the required effect.

## **Network Challenges**

Our aircraft and, indeed, all new capabilities will be increasingly defined by what they contribute to the network and what they exploit on the network, and rather less by how fast and far they can fly. Moreover, the network will connect a range of actors drawn from a variety of organisations and nations. The legal consequences of this diverse group acting together will, therefore, need deep consideration, as will the determination of delegated authorities. If authority is overly centralised, the potential tempo of decision-making throughout the network will suffer, and the collective power of the network will be diminished.

## **The Network That Countered the Iraqi Scud Threat**

The concept of a network extends beyond kit: beyond radios, gateways, datalinks and fibre optic cables. It is the purpose *not* the means of connection and communication that defines

the network. In 2002-3, the US and its partners developed a bespoke network to counter Saddam Hussein's Scud threat in the Western Desert of Iraq. The challenge was to deter Iraqi Scud activity and if this failed, to detect and destroy the Scuds, wherever they were deployed. The Western Desert was the focus area because Scuds sited there could reach a range of sensitive and critical targets in the Middle East, not least Israel. For the first time, an airman, General 'Buzz' Moseley, was designated the *supported* commander for the mission and the network was built, developed, exercised and rehearsed in Nevada.

There were 3 critical requirements of the network: detect the Scud, decide a response, then execute an attack, all within 10 minutes. This was delivered by a range of actors in the air and on the ground, connected together in a network of sensors, decision makers and the deliverers of lethal effect. The combination of the sheer expanse of the Western Desert and the tight timelines drove a philosophy of empowered, forward, persistent presence. Empowerment required downward delegation of decision-making authority to aircraft captains and the development of a system that circumnavigated any possible 'CAOC-idling loop'. A 'Time Sensitive Targeting' (TST) team was embedded within the CAOC to oversee and police the network. A 'Bullseye' system<sup>12</sup>, familiar to anyone practised in air defence, was adapted for air-to-ground use, and every element of the system, individually and collectively, was exercised, refined and exercised again before it was deployed to the Middle East. In the event, whether through deterrence or not, no Scuds were employed in the Western Desert. The TST system was adapted, however, to provide highly responsive Close Air Support to forces on the ground and formed the basis of the solution to the 'Troops in Contact' challenge that was to dominate air power delivery in Iraq and Afghanistan.

## **Networked Enabled Warfare and The Next Generation Air Force**

As we look beyond Typhoon and towards Tempest and our Next Generation Combat Air capabilities, we must think from the inside out; that is to say that we must start with the computer or the systems and the information exploitation and exchange capability we need before we build the platform around them. We must also consider connectivity from the outset, including how we connect to a range of offboard systems, whether they be swarming UAVs or other systems in the space or cyber domains. The Next Generation Air Force may not enjoy the same degree of technical superiority over our adversaries we have experienced in recent years, but through the development of Network Enabled Warfare it can retain its competitive advantage by better integrating human and machine into networks, by exploiting the analytical capacity and capabilities resident in the UK, and by ensuring the right information is available to the right person at the right time, and in the right domain.

***My Eighth Air Truth: The rapid delivery of understanding in the battle space is a unique strength of air (and space) forces, but ambiguity will continue to challenge decision makers.***

The Clausewitzian 'fog of war' and the friction inherent in conflict make knowledge and understanding of the battlespace the vital ground of operations. For the counter-insurgency

operations in Afghanistan, it was this knowledge that drove the direction, timing and tempo of the campaign. The enduring nature of the operation allowed the deployment over time of significant numbers of troops and equipment which, when supported by an umbrella of persistent unblinking sensors on satellites and aircraft, delivered a level of insight not seen previously. However, high-readiness forces deploying into operational theatres at short notice, are much more dependent on the rapidly deployable ISTAR capability of our air and sea platforms.

In the case of Libya in 2011, the much reduced ground presence and the limited ability of maritime assets to look beyond the coastline, meant that the Alliance exploited the height and agility of NATO's air and space platforms. These platforms were equipped with cutting-edge sensor technology, staring persistently across most of the electromagnetic spectrum, and surveying vast areas deep into the country. Writing about the early operations in Afghanistan, but reflecting the experience over Libya, the eminent US historian Ben Lambeth observed that the transformation in modern operations has been, 'The dominance of fused information over platforms and munitions as the principal enabler of the campaign's success in the end'.<sup>13</sup>

## **RAF Analysts Making Sense**

Whilst air force equipment is used to sense activity, it is the air force analysts in the air and on the ground who *make sense* of the activity, rinsing out every ounce of capability from the platforms, fusing the information to create knowledge and understanding of the battlespace. Critical to their efforts is the layering of assets and the generation of cross-cueing opportunities. Exploiting the synergies within the RAF's fleet of ISTAR aircraft, whilst operating within a coalition framework, was the primary purpose of the RAF's Project BIISTO (British Integrated ISTAR Support To Operations). The unintelligent tasking of RAF intelligence assets in Afghanistan in 2009 was the source of frustration and Project BIISTO involved a number of British officers, serving in a variety of headquarters, who 'massaged' tasking to better combine and exploit UK capabilities. For example, the all-weather wide area surveillance capability provided by the Sentinel was used to cue RAF manned and unmanned combat and reconnaissance aircraft, which were equipped with the high resolution electro-optical sensors necessary to identify enemy activity on the ground, which could then be dealt with through appropriate air or ground action.

Determining ground truth is fraught with challenge and the information available in war is rarely sufficient (or timely enough) to enable decision-making in the comfortable blanket of absolute knowledge. In Kosovo, NATO's aircraft attacked what was thought to be a Serbian military convoy, but turned out to be a line of civilian tractors and trailers, and in Afghanistan, coalition aircraft attacked a large group of so-called Taliban massing for an attack, which turned out to be villagers gathering around a fuel truck stuck in mud. On both occasions, commanders made the limited facts available fit a flawed hypothesis. In the case of Kosovo, the attack ceased when a formation of RAF Harriers arrived overhead and transmitted concerns about the convoy being targeted, demonstrating the value of a second opinion from the

third dimension. In the Afghanistan example, the aircrew suspected that all was not well but unfortunately accepted the judgement of the ground commander.

## **Red Card Holders**

Whoever has the best available information should normally own the decision; however, the enormity of the consequences of decisions may require the authority to decide to be held at a higher level. If time allows, boards can convene and expert advice sought; however, often the time available is measured in seconds and minutes and judgments need to be based on a rapid conversation, not a well-constructed and prepared brief. During Operation Shader this has been a daily occurrence for the 'Red Card Holders', who demonstrated exceptional and persistent excellence in their decision-making, despite the ambiguous and often contradictory information at their disposal.

## **The Reaper Force**

The quality of decision making of the 'Red Card Holders' in the CAOC has been matched by that in the cockpits of our aircraft over the battlefield and in the Reaper cabins stationed in Nevada and Lincolnshire. The Reaper operators, whilst many thousands of miles distant from the action, are arguably the RAF's deepest in-theatre experts. Most warfighters deploy episodically on operations; Reaper operators are employed permanently. Although they may not smell the cordite, they develop uncommon intuition and offer insights unmatched by those physically present on the battlefield. In Iraq and Afghanistan they played a critical role in the coalition's Counter-Improvised Explosive Device (C-IED) activity, using their persistent presence and pervasive sensors to establish an excellent understanding of 'normal activity' and thus enabling them to detect the abnormal and therefore the suspicious. This capability extends beyond the technical: on one night, a potential IED-planter was discovered digging a device into a field near an important road. An aircraft was on the verge of dealing with the bomber when an RAF Reaper arrived overhead and the crew used their deep operational experience to deduce that the bomber was in fact a farmer working in his field at night to avoid the high day-time temperatures. A second opinion from the third dimension can save lives. Experience counts too.

## **Decision Making at Home**

At home, our National Representatives (NATREP) are RAF wing commanders who play a critical part in the command and control of domestic air policing. The more significant decisions are made at a higher level and the NATREP's challenge is to rapidly assimilate the facts and to simply and succinctly describe them to a higher-level decision maker in a way that allows for timely decision making. Difficult at the best of times, this was a particularly complex challenge during the execution of the Air Security Plan for the London Olympics in 2012, when the forces were diverse, including deployed ground-based air defence batteries, radars, visual observers, sniper-equipped helicopters and supersonic fighters. Critical to the effort was timely decision making; by that, I mean making decisions on the employment of lethal force that could affect thousands of lives within minutes and based on scant

information. Under such circumstances, to *not* make a decision was in itself a decision. Whilst the threat did not manifest itself during the London Olympics, the events of 9/11 underline the requirement to assemble and thoroughly exercise both the deployed forces and the decision makers, preparing them to employ lethal force with precision and good judgement. On a lighter note, our Olympic experience provided another example of inappropriately making facts fit the theory. One evening a suspicious light was spotted in the sky to the East of the Olympic stadium by one of the deployed visual observers. A Lynx helicopter was scrambled by the Air Command Operations Centre from the deck of HMS Ocean, which was at anchor in the Thames near Greenwich, and ordered to investigate. After a few minutes, the Lynx helicopter crew reported back that they were unable to intercept the aircraft as it was the planet Venus!



London Olympics 2012.



RAF100 Flypast.

***My Ninth Air Truth: The future success of the RAF depends on transforming how we train.***

In recent years, the RAF has been committed to operations at a level of tempo and complexity not seen in generations. Chests on the parade square are adorned with medals of all varieties, reflecting the exceptional quality and the quantity of the operational contribution made in the air and on the ground. Today, we have an air force with a level of combat experience that is the envy of air chiefs around the world. And yet, the necessity of placing an almost total focus on warfighting risks neglecting what Trenchard described as ‘the extreme importance of training’<sup>14</sup> and believed would be the *making or marring* of the future of the Air Force. Today, technology, cost and, increasingly, the environment are driving the ‘extreme importance’ of a paradigm shift in how we train.

Advances in technology present both opportunity and threat: opportunities we are yet to seize and threats to which we must respond. Training must be included in this calculus. The most obvious technical opportunity rests within the synthetic environment. No longer should thinking about synthetic training be constrained to simulators, and no longer should synthetic training be dominated by the operations of individual devices. The rapid expansion of the gaming industry has resulted in synthetic environments with more than 10 million concurrent players. Add to this the advances in virtual reality and augmented reality and it



quickly feels like our current thinking on simulators is on a level with the ZX Spectrum in the world of Apple and Google. Moreover, and following on from the growth of E-sports, is it inconceivable that E-wars will be fought in the virtual battlespace?

## **RAF Synthetic Training**

Synthetic training has played a critical role in the RAF since the 1930s. Indeed, following World War II, Air Marshal Robert Leckie said 'The Luftwaffe met its Waterloo on all the training fields of the free world where there was a battery of Link Trainers.'<sup>15</sup> In the early 1990s, the RAF fielded cutting-edge technologies that tracked pilot retinas to deliver high resolution visual imagery in critical areas within the simulator field of view and played a central role in driving NATO efforts to better understand the opportunities provided by Mission Training through Distributed Synthetics. More recently, the RAF contributed to the Mace studies that informed SDSR 2010 and set a target of a 50:50 balance for RAF, RN and Army live:synthetic front-line training. Unfortunately, progress towards this ambitious target has retreated over time and we are many years from fielding distributed synthetics that connect a virtual network of disparate training audiences across the environments. Nevertheless, the Defence Operational Training Capability for the Air (DOTC(Air)) environment promises to deliver a step-change in how we train, exercise and rehearse. It will embrace the live and virtual environments and offers economic and efficient training at home and when deployed, including on-board the Queen Elizabeth Class aircraft carriers. Critical to the delivery of DOTC(Air) is the Air Battle Training Centre at RAF Waddington, which has played (and will continue to play) a critical role in the delivery of RAF Live-Virtual-Constructive collective training.

## **Protecting Capability**

Part of the training challenge posed by technology is the need to protect sensitive capabilities, such as those possessed by the F-35 Lightning, which may be compromised during live training. A synthetic, secure environment is critical if we are to train, exercise and rehearse away from the persistent stare of malign actors. This must not drive training solutions confined to one aircraft type, such as the F-35, or isolate aircraft from other members of the network. The preparations for the Gorazde extraction in 1994/5 and the Western Desert of Iraq in 2002-3, teaches us the benefit, if not the necessity, of all players on the network being trained, exercised and rehearsed together. Moreover, the increasing performance of our aircraft and their weapons drives a demand for ever increasing volumes of airspace in which to train at a time when the rise in civil air travel and the associated protected airspace shows no sign of abating. Again, the synthetic environment offers an obvious alternative way to square the military training circle.

## **Credible Replication**

Another challenge for training technology is the replication of the physiological and psychological experience of warfighting. A flight in the Typhoon simulator does little to prepare pilots for air combat fought at 9g. Moreover, no matter how demanding the instructor



or supervisor, a mistake in the simulator does not replicate the consequence of a mistake in the aircraft. When considered alongside the economic dimension, these factors support live flying and work to explore the concept of 'surrogacy'. Just as a Land Rover can be used to train soldiers in Foxhound combat vehicle operations, so could the Hawk T2 provide the physiological and psychological experience necessary to act as a surrogate training platform for Typhoon pilots.

## Striking the Right Balance

Debates about the live-synthetic balance of flying have many more factors than space here to describe, including notably the issue of culture: we have yet to see the first 1,000 hours live/simulator badge presented to pilots. Live-synthetic discussions occasionally have Luddite resonance with the narrow-minded debates of yesteryear surrounding the introduction of female fast jet pilots and unmanned aircraft. Such arguments are unthinkable today as both are central and critical elements of the RAF front-line (although both still do not exist in the numbers we need). Decisions on synthetics today must be similarly forward looking.

## Delivering Affordable and Relevant Training

Affordability remains an Achilles Heel of air power, so to remain relevant to the Nation's needs, the RAF needs to remain affordable and to counter the orthodoxy that the spiral development of capability is inevitably accompanied by spiralling costs, which can only be addressed through delay and/or descoping of programmes. The path to affordability has many different routes, of which synthetic training is a crucial one. We must ensure that every live flying hour is consumed because it is necessary *not* because it is possible. The key issue is to nail the requirement and to understand the benefits and risks associated with the various live:synthetic blends. Discussions on the live flying hour requirement must not suffer from the intellectually corrupt yesteryear defences of the *status quo*. We must question every live flight and consider carefully the value of every air show and flypast. The benefits could be great: a reduced requirement reduces the amount of live flying hours required from the aircraft fleet (and lowers the carbon footprint), which drives reduced maintenance and spares support, which could drive a reduction in support staff and reduced numbers of aircraft. There are risks, and it is very easy to adopt a highly efficient operating model for a peace-time air force, but one that is unable to surge and be sustained in times of conflict. A manning philosophy and contract solutions need to be developed that will ensure the air force can readily transition between the fundamentally different operating conditions of peace and war. Moreover, we need to think deeply how our peacetime posture would contribute to deterrence, if most of the training effort involves aircrew flying in simulators. As in most issues, it is a matter of balance. Technology provides opportunity, but the economics drive the necessity for change. Irrelevance and unaffordability are two sides of the same coin; the RAF must, therefore, deliver affordable air power if it is to remain relevant, and this requires a paradigm shift in the way we train, prepare and rehearse our forces.

***My Tenth Air Truth: Day 1 is the most dangerous day of any operation.***

***A superior pilot is one who combines his superior knowledge with his superior judgement to avoid having to use his superior skill.***

**Frank Borman**

The last three decades have been marked by enduring and slowly unfolding operations in the Balkans, the Middle East and Afghanistan. Consequently, the RAF has amassed deep wells of operational experience, little of which prepares you for Day 1 of a new operation. Day 1, that first day of an operation when the pulse races at the thought of flying over an unfamiliar country, facing a foe of uncertain capability and fighting spirit. Often the operation is preceded by days, if not months, of heightened tension and febrile public and parliamentary debate. Tactical plans may have been hurriedly prepared and, with delays, become incredibly clever but overly complex works of art that will fail to survive first contact with the enemy. 'H-Hour' is rarely known until the day of action. The challenge for any commander at the onset of an operation is to understand the level of risk acceptable to their Government and to ensure this judgement is translated in a way that makes sense and is replicated all the way from the CAOC to the cockpit. 'Press-on-itis' is a well-known condition that afflicts most aircrew at some point in their flying career. It happens on operations and in training, when the enthusiasm for the mission clouds one's judgement of the risks and is normally only diagnosed after the act. The prevalence of press-on-itis is at its greatest on Day 1, and what follows are my experiences of the Day 1 phenomenon.

**Day 1: 30 August 1995**

For me, my first Day 1 of combat was also the first Day 1 for the RAF's 'New Harrier'<sup>16</sup> Force and the first Day 1 for NATO combat forces. Perhaps, therefore, 30 August 1995 stands as an exemplar of Day 1 risks. The Balkans had imploded over the summer of 1995. In July, the small Bosnian town of Srebrenica was 'ethnically cleansed' by forces under the command of the notorious war criminal General Ratko Mladic, and many thousands of Muslims were slaughtered; the UN peacekeeping mission was failing, and UN peacekeepers were being taken hostage; over 100,000 Croat soldiers attacked the Serbs in Krajina; and then many innocents were killed in the infamous mortar attack on a Sarajevo market square. The patience of the international community had exhausted, and NATO responded on 30 August 1995 with the launch of Operation Deliberate Force. On Day 1, I had the privilege of being the first RAF commander to lead a NATO mission in combat at the head of 'Strike Package Delta', a formation of 24 RAF, French and US aircraft, drawn from ships and land bases in Italy tasked to destroy a Serbian armaments storage facility near Sarajevo. The familiar practice of 'running for the spare' was well exercised that day as both my wingman and I swapped our broken aircraft for serviceable ones, minutes before the planned take-off time. Nothing in that mission went as planned or expected; all that *could* go wrong *did*. The weather was poor, the communications were jammed and a French aircraft in my formation was shot down as they attacked their target. Fortunately, both aircrew survived both the shootdown and the pot-shots taken at

them as they descended under their parachute canopies, but they endured an extended period of incarceration by the Serbs until they were released 4 months later. The French aircraft was flying ahead of me – the aforementioned delays on the ground meant that I filled the ‘tail-end charlie’ position. I now know that the wall of noise on the radio, a mix of a persistent and loud hissing sound interspersed with a heavily-accented French voice, was not enemy jamming but panicked friendly forces responding to the shoot down. Despite their efforts, it was only on landing that I realised an aircraft had been downed, which is slightly embarrassing and unfortunate given that I too was shot at by the same Serbian air defence unit on Mount Igman. Fortunately for me, my eagle-eyed wingman (a USMC pilot – Semper Fi) alerted me to the 2 SA-14 infra-red missiles arcing towards my aircraft, giving me time to defeat them. Undaunted by the experience, we pressed on and reattacked the target (what was that lesson from the Falklands about not reattacking?) with somewhat limited success.

### **Day 1: 24 March 1999**

The opening day of Operation Allied Force also provided a good example of the ‘Day 1’ phenomenon. A combination of weather and ‘press-on-itis’ meant attacks continued to be prosecuted despite targets being obscured by smoke, leading to mission failure. Moreover, for the RAF Tornado aircrew, Day 1 operations involved flying from Germany to conduct long-range attacks in Serbia; it’s a long way to fly and not press on to the target. There are, of course, valid reasons to continue with an attack or a mission, particularly if friendly forces on the ground are under fire. This challenging risk calculus, whilst at its most uncertain on Day 1, applies throughout an operation. Balancing the risk to life against the risk to mission is never easy, particularly when that mission involves the saving and protecting of brave men and women on the ground. Nowhere is this challenge better demonstrated than by the considerable and courageous efforts of everyone involved in the operations of the helicopter-borne Medical Emergency Response Teams in Iraq and Afghanistan.

### **Day 1: 19 March 2003**

The most effective antidote to ‘press-on-itis’ and Day 1 risks is preparation. This includes training, rehearsal, education, a deep understanding of ROE, the Targeting Directive and the well-articulated intent of commanders – all tested and debated in the crew room before you reach the briefing room, let alone the aircraft. Easier typed than delivered, but this is why I believe Day 1 of Operation Telic in the Western Desert of Iraq on 19 March 2003 went far smoother than was expected or feared. No force could have been better prepared. Much of the detail of that day and the rest of the warfighting phase of the operation remains obscured by the cloak of secrecy, but it is my view, as both a pilot during the Operation and as author of a subsequent MOD report<sup>17</sup>, that the lessons of 2003 are worthy of in-depth study and are entirely consistent with the truths above.

### **The Service Test**

The RAF enters its second century as an organisation that is respected, valued and employed. But as we build towards the Next Generation Air Force, we must guard against prioritising

the business of Defence ahead of the business of warfighting. Rather, we would do well to remember Trenchard's challenge for the RAF in 1920:

'The test of every fighting Service is war. Its organization, training, distribution, systems of command and administration must always be primarily governed by this consideration. Peace has its own problems and difficulties, financial and other; but in solving them we must always keep war in the forefront of the picture and try to foresee its possibility, probability, locality and nature'.<sup>18</sup>

Whilst some consider truth to be a casualty of war, I contend that my 10 Air Truths are the conclusions of war. I accept also, however, that no one man has the monopoly on truth or wisdom and, as the Swedish scientist Jons Berzelius observed:

***The habit of an opinion often leads to the complete conviction of its truth, it hides the weaker parts of it, and makes us incapable of accepting the proofs against it.***

## Notes

<sup>1</sup> Churchill, Winston. *The Gathering Storm*. Boston: Houghton Mifflin, 1985, page 100.

<sup>2</sup> Colourfully described by Squadron Leader Jerry Pook MBE DFC in *RAF Harrier Ground Attack: Falklands*. London: Pen & Sword Books. 2007.

<sup>3</sup> Campbell, Alastair, and Richard Stott. *The Blair Years: Extracts from the Alastair Campbell Diaries*. London, Arrow Books, 2008, pages 362-404.

<sup>4</sup> The British Army describes 77th Brigade's aim as 'to challenge the difficulties of modern warfare using non-lethal engagement and legitimate non-military levers as a means to adapt behaviours of the opposing forces and adversaries.' "77th Brigade." The British Army. Accessed August 12, 2019. <https://www.army.mod.uk/who-we-are/formations-divisions-brigades/6th-united-kingdom-division/77-brigade/>.

<sup>5</sup> John Keegan, "Please Mr. Blair never take such a risk again," *The Daily Telegraph* (London), June 6, 1999.

<sup>6</sup> Robertson, George. NATO Speech: 21 March 2000. March 24, 2000. Accessed August 12, 2019. <https://www.nato.int/docu/speech/2000/s000321a.htm>.

<sup>7</sup> *ibid*.

<sup>8</sup> Clausewitz, Carl Von, Michael Howard, and Peter Paret. *On War*. Princeton, NJ: Princeton University Press, 1989, page 88.

<sup>9</sup> Professor Michael Howard, *Military Science in the Age of Peace*, (The RUSI Journal, Volume 19, No. 2, March 1974).

<sup>10</sup> Rommel, Erwin; Liddell Hart, Basil Henry; and Paul Findlay. *The Rommel Papers*. New York: Da Capo, 2003.

<sup>11</sup> Royal Air Force. *Royal Air Force Strategy: Delivering a World-Class Air Force*. RAF High Wycombe Air Media Centre, Crown Copyright, 2007, page 23.

<sup>12</sup> The position of any activity of interest is provided by stating the bearing and range from a pre-defined position (the Bullseye).

<sup>13</sup> Benjamin S Lambeth. *Air Power Against Terror*: Rand Corporation. 2005.

<sup>14</sup> Trenchard Memorandum – Permanent Organisation of the Royal Air Force - 1919.

<sup>15</sup> Van Hoek, Susan; Link, Marion Clayton (1993). *From Sky to Sea, A Story of Edwin Link* (2nd ed.). Flagstaff, AZ: Best Publishing Co.

<sup>16</sup> Harrier GR5/7/9 or Harrier II (USMC).

<sup>17</sup> Directorate of Operational Capability: *Op Telic Lessons Study Vol 1*. MOD. 2003.

<sup>18</sup> *Aspects of Aviation*: An address by Trenchard to an Air Conference, 1920.

## Viewpoint

# An Ethics Framework for Autonomous Weapon Systems

By Professor Peter Lee

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**Biography:** Peter Lee, Professor of Applied Ethics, is the Director, Security and Risk Research and Innovation, at the University of Portsmouth. His research interests span the politics and ethics of war, the ethical and other human aspects of RPAS operations in military, policing and wider security contexts, and the ethics of autonomous weapon systems. In 2016 he was granted unprecedented research access to the two RAF Reaper squadrons for his book, *Reaper Force: Inside Britain's Drone Wars* (October 2018). He is currently an Expert Adviser to the UK All Party Parliamentary Group on Drones. From 2008 to 2017 he taught Ethics and Law of War at Royal Air Force College Cranwell for King's College London and the University of Portsmouth respectively. Peter holds a PhD in War Studies from King's College London which explores the emergence of Western war ethics. From 2001 to 2008 he served as a Royal Air Force chaplain.

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**Abstract:** This essay draws on extensive personal engagement in numerous national and international events and discussions, to explore some of the key ethical challenges presented by the development and deployment of autonomous weapon systems (AWS). Some of these ethical reflections are process driven, while others are outcome focused. I sketch out a technological, political and operational landscape, bringing together several of the elements that must combine to provide AWS capability within an ethical framework. Practically, each of these elements is hugely complex; this paper can only hope to provide an overview of the challenges, rather than an in-depth analysis. Whilst distinct legal questions will also be raised by these elements, the priority here is to outline an AWS ethics framework for current and future discussion. Throughout, I assume that war ethics are *comparative* – making better or worse choices – rather than *ideal* – making simple choices between good and evil – in complex, seemingly impossible situations.

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## Introduction<sup>1</sup>

Since 2011 the main strand of my research and writing has addressed the ethical aspects of remote air warfare through the lens of the RAF Reaper Force. In parallel, I have participated as an ethicist in numerous national and international discussions and events concerned with rapid technological advances towards autonomous weapon systems (AWS). Visualizing the breadth and complexity of the many challenges of AWS is essential in order to address the ethical considerations at scientific, policy and operational levels. Practically, each of these elements is hugely complex so, in working towards an ethics framework for AWS, this paper can only provide an overview rather than an in-depth analysis of several constituent parts.

In 2014 the International Committee of the Red Cross convened an Expert Meeting on 'Autonomous Weapon Systems: Technical, Military, Legal and Humanitarian Aspects' and has hosted regular discussions since.<sup>2</sup> Separately, in 2017 the UN convened a 'Group of Governmental Experts related to emerging technologies in the area of lethal autonomous weapons systems (LAWS)'.<sup>3</sup> However, any discussion of AWS is problematic, for several reasons, across multiple fields. These include: the difficulty of describing and operationalising autonomy; the different types and purposes of AI that are needed to enable autonomy, including predictability; human-machine system working and robustness; future communications which rely on nascent quantum entanglement capabilities; and human and machine bias. Whilst each of these also raises legal questions, my emphasis below is on ethical considerations. In addition, new ethical considerations are added to already-disputed ethics of war. Just War theory has, for centuries, challenged two opposing approaches to war: *realism* and the unconstrained use of force in the pursuit of power on the one hand, and on the other, *pacifism*, which rejects all use of military force and the killing involved as inherently wrong.<sup>4</sup> Like any weapon, AWS could also be used outside the domain of war, but this paper focuses on its use in international armed conflicts and non-international armed conflicts.

To provide the basis of an outline ethics framework for AWS, this paper conceptualises a future lethal autonomous aircraft system (LAAS) – popularly referred to as lethal autonomous drones – by taking the MQ-9 Reaper Remotely Piloted Aircraft System as a starting point and considering the implications of how a future variant might operate when elements of its functionality are delivered autonomously using AI. In the subsequent sections, the following key terminological, theoretical and other challenges will be outlined: the difficulty of describing and operationalising autonomy; the different types and purposes of AI that are needed to enable autonomy, including predictability; human-machine system working and robustness; future communications which rely on nascent quantum entanglement capabilities; and human and machine bias. The paper concludes by outlining an ethics framework for AWS under four headings: overarching ethics of war, human responsibility, the methods and means of war, and risk assessment and mitigation. Whilst the potential for the proliferation of AWS technology beyond state actors clearly exists, as do associated legal questions, the emphasis is on developing a proposed ethics framework which applies to states and not to individuals,

groups or other non-state actors. Further, the ethics framework is rooted in just war reasoning as an ethic of comparative, not absolute, justice.<sup>5</sup>

## **Autonomy – a contested concept**

Definitions of autonomy have important operational, legal, ethical and political dimensions which go far beyond simple semantics. For example, the UK Government's official position on fully autonomous weapons was set out by the Parliamentary Under-Secretary of State for Foreign and Commonwealth Affairs in a 2013 Parliamentary debate on Lethal Autonomous Robotics:

[T]he Government of the United Kingdom do not possess fully autonomous weapon systems and have no intention of developing them. Such systems are not yet in existence and are not likely to be for many years, if at all. Although a limited number of defensive systems can currently operate in automatic mode, there is always a person involved in setting the parameters of any such mode. As a matter of policy, Her Majesty's Government are clear that the operation of our weapons will always be under human control as an absolute guarantee of human oversight and authority and of accountability for weapons usage.<sup>6</sup>

The Under-Secretary went on to state that 'We cannot develop systems that would breach international humanitarian law, which is why we are not engaged in the development of such systems'.<sup>7</sup> Note, however, that the UK Government's 'intention' did not exclude several possibilities: development of 'fully autonomous weapon systems' at some point in the future; the development and deployment of systems that fall short of 'fully autonomous'<sup>8</sup>; or fully autonomous non-weapon systems. Despite these potential caveats – and the lack of a definition of what 'fully autonomous' means – there is also reference to weapons 'always be[ing] under human control'. Not in the sense of individual weapon engagements but 'as an absolute guarantee of human oversight and authority and of accountability for weapons usage'.

Neither conventional just war ethics, nor compliance with IHL, specifies a requirement for continuous human control of weapons.<sup>9</sup> However, the point is politically and culturally sensitive and the lack of direct human control of weapon release is a key component of the argument by the Campaign to Stop Killer Robots that AWS are 'abhorrent, immoral, and an affront to the concept of human dignity and principles of humanity'.<sup>10</sup> While there is not the scope here to develop this 'human dignity' argument, Amanda Sharkey provides a useful starting point for further enquiry: 'If it is accepted that there are many weapons, artifacts, and human behaviours that are held to be against human dignity, then this itself becomes a reason for not relying too heavily on human dignity in arguments against AWS, as distinct from other means and weapons of warfare'.<sup>11</sup> Extending my 'comparative justice' approach to the idea of 'comparative dignity', human dignity has been violated through enslavement, rape, torture and myriad abuses throughout the history of war, and I remain unconvinced that AWS provide a special case which trumps all other violations.



The Campaign to Stop Killer Robots also used similar language to that of the UK Government when, in 2013, it called for a ‘pre-emptive and comprehensive ban on the development, production, and use of fully autonomous weapons.’<sup>12</sup> Fully autonomous weapons were those which had the capability to ‘choose and fire on targets on their own.’<sup>13</sup> It is not clear if The Campaign to Stop Killer Robots was simply demanding what the UK Government appeared to be offering – human control of weapon systems – or if the campaign was driven in part by a broader pacifist ideology which opposes all military violence, with ‘fully autonomous weapons’ serving as a campaign focus. Every government, however, will adopt its own position and not necessarily be open to human control of AWS, so the Campaign to Stop Killer Robots provides a timely global challenge.

## Degrees of autonomy

There are further semantic points of which to be aware in the burgeoning literature on autonomy, which extend to the context of AWS. For now, however, this paper suggests that a crucial terminological battle is – or should be – over the word ‘fully’ and what it means in relation to autonomy in weapon systems. I have written elsewhere about what can be referred to as AI and autonomy in an idealised philosophical sense and also in the sense of more ‘limited machine autonomy.’<sup>14</sup> In the former – idealised autonomy – AI achieves or exceeds human equivalence (the ‘singularity’) in functioning, reasoning and decision-making, and is represented in science fiction films. But even these science fiction autonomous robots do not claim or allude to the next and ultimate level of artificial intelligence – Artificial General Intelligence (AGI). AGI occurs when computer-driven AI reaches a state of self-learning that exponentially increases its knowledge on a continuous, positive-feedback learning loop.<sup>15</sup>

Machine limited autonomy based on AI more closely reflects the practical experience of AI theorists and practitioners. In a military context, a UK Joint Doctrine Note captured that limited scope in 2011:

An autonomous system is capable of understanding higher level intent and direction. From this understanding and its perception of its environment, such a system is able to take appropriate action to bring about a desired state. It is capable of deciding a course of action, from a number of alternatives, without depending on human oversight and control, although these may still be present. Although the overall activity of an autonomous unmanned aircraft will be predictable, individual actions may not be.<sup>16</sup>

Recent developments and testing of military technology in the UK indicates the future trajectory when it comes to AWS. In 2016, the Royal Navy hosted Exercise Unmanned Warrior which, in conjunction with 40 industry and other partners, enabled the testing of ‘unmanned and autonomous vehicles... to remove human operators from the most tedious, unpleasant and dangerous activities, such as mine-laying and recovery and anti-submarine operations.’<sup>17</sup> These practical applications of emerging technology are consistent with the UK Government’s stated aims set out above.

In 2018, the British Army hosted Exercise Autonomous Warrior with the specific aim of ‘test[ing] and evaluat[ing] the effectiveness of robotic and autonomous systems (RAS) on the battlefield.’<sup>18</sup> Defence Minister Mark Lancaster reinforced the vision for the future place of autonomy in UK military doctrine and practice when he said, ‘Autonomous Warrior sets an ambitious vision for Army operations in the 21st Century as we integrate drones, unmanned vehicles and personnel into a world-class force for decades to come.’<sup>19</sup> While the language of autonomy is used more prominently here than in Exercise Unmanned Warrior in 2016, there is still not explicit mention of autonomous weapon systems that could be deployed in a lethal attack role, let alone a ‘fully autonomous weapon system’ of the kind that UK policy (at least at the time of writing) and The Campaign to Stop Killer Robots both reject.

Yet, despite this flurry of activity – a mere glimpse of worldwide autonomous systems development – agreed definitions are no closer. A small sample of that literature highlights the extent of the challenges, definitions and practicality, of autonomous weapon systems. In a US military-focused context, Massie discusses the extent of autonomy, the role of AI, machine-human working and the importance of trust in systems.<sup>20</sup> In 2014, the Birmingham Policy Commission examined drone use in the UK and discussed many of the challenges of LAWS at great length. The Commission challenged the UK Government to ‘take a leading role in discussions to build an international consensus around a set of norms to regulate, if not ban, LAWS.’<sup>21</sup> It helpfully defined AWS as ‘ones that have the following properties: *automation*, *volition*, and *intention*.’<sup>22</sup> These properties were sourced from Marra and McNeil, who expand further:

Autonomy also requires some decision-making agency, which is captured by *volition*, or “choice in action or thought,” and *intent*, or deliberate “pursuit of goals.” Truly autonomous machines may also actually be able to learn, meaning they can draw conclusions based on past experience and incorporate these lessons into future actions. This baseline distinction between automation and autonomy offers a useful starting point.<sup>23</sup>

These concepts of automation, volition and intention get even more interesting – and attributed with philosophical capabilities that are typically identified as human – when traced back even further to Clark’s 1999 theorising on Cyborged Ecosystems.<sup>24</sup> The agency required for autonomy includes ‘independence of comportment’ and ‘a sufficiently conscious mind’; the necessary automation includes ‘the capacity to operate without outside intervention’; volition extends to ‘defining its own goals and then formulating and executing strategies for attaining them’; before, finally, ‘in order to be significantly autonomous an entity must be intentful, and actually exercise its volition.’<sup>25</sup>

Perhaps increasing the usefulness of these concepts is Clark’s contention that ‘autonomy should be measured on a continuous scale.’<sup>26</sup> At one extreme would we find ‘truly autonomous’ systems or, to use more recent terminology, ‘fully autonomous’ systems referred to above by the UK Government, The Campaign to Stop Killer Robots, the Birmingham

Commission, as well as by Human Rights Watch.<sup>27</sup> Lower levels of autonomy would still be available, but would go beyond mechanised automation. Clarke's insights undermine an important statement in the Birmingham Commission report, where it says: 'Put simply, a weapons system is either autonomous or it is not – there is no spectrum of autonomy.'<sup>28</sup> The proposition that emerges from this brief discussion is that it is both practically and conceptually possible to have AWS that fall short of being 'fully autonomous' however that contested phrase is understood. AWS become practically possible because of the possibility of limited levels of autonomy which, in turn, would rely on varying applications and capabilities of AI as identified in the next section.

## Different types and purposes of AI

Definitions of AI are proliferating but a useful description by Hopgood in 2003 is a good starting point: 'Artificial intelligence is the science of mimicking human mental faculties in a computer.'<sup>29</sup> While it may not always be helpful, comparisons of AI and human intelligence can provide a convenient shorthand to help non-experts grasp what AI is capable of.<sup>30</sup> With his emphasis on operationalizing AI, Hopgood avoids – even cautions against – hyperbolic claims about what AI is and what it can achieve. He provides understanding for the non-expert by offering a spectrum of intelligent behaviours (see Figure 1 below) and explaining how it is the middle of the spectrum that AI finds most difficult to replicate. It turns out that 'common sense' is vastly more complex than first appreciated by AI scientists several decades ago, and that the brain operations we put into understanding what we see are tremendously difficult to replicate artificially.

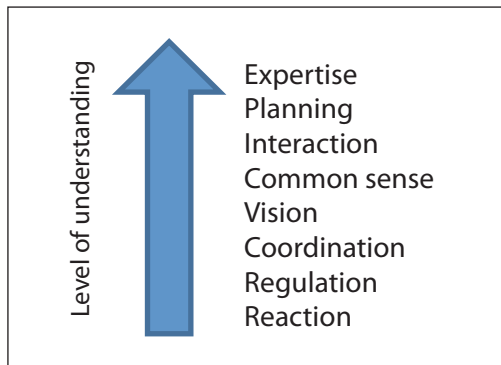


Figure 1<sup>31</sup>

He also sets out two broad AI categories, distinguishing between 'explicit modelling with words and symbols' and 'implicit modelling with numerical techniques,' then identifies a number of AI techniques: neural networks, genetic algorithms, simulated annealing, artificial immune systems and fuzzy logic.<sup>32</sup> In terms of applying these techniques in complex AI systems, Hopgood offers a 'blackboard system.'<sup>33</sup> Such a system seeks to replicate human teamworking by combining different AI techniques on an integrated system to address multiple elements of an overarching complex problem.

Such an approach offers a practical way ahead in the operationalising of AWS where different types of AI will most likely be needed for different elements of the system. For example, knowledge-based AI will be needed to interpret and apply complex rules of the kind that would enable a system to conform to proportionality constraints in the use of lethal force. In contrast, only a limited range of AI capability might be needed for the repeated, mundane and predictable tasks of automated take-off and landing of an air vehicle.<sup>34</sup> Furthermore, the AI requirements for human and object recognition will differ from those needed for flying safely in either civil airspace or the military-controlled battlespace.

One further AI technique that has gained a high public and scholarly profile is 'deep learning' in neural networks. Schmidhuber suggests one recurring use of deep learning is unsupervised learning which, in turn, 'can facilitate both SL [Supervised Learning] and RL [Reinforcement Learning]'.<sup>35</sup> Supervised learning is particularly effective at pattern recognition, while reinforcement learning occurs in the absence of a 'supervising teacher'.<sup>36</sup> Each of these is one of many techniques that can be refined, applied, self-refining, and so on. However, to be legal, ethical and operationally effective, in a lethal autonomous aircraft system each technique will have to be predictable and robust enough to underpin decision-making that may cost lives and inflict physical destruction.

Given the likely surveillance modes of any future autonomous aircraft system or drone, unsupervised learning would be useful for encoding vast amounts of video feed, and enabling more focused analysis on smaller search areas of interest. Any such analysis would need – in some kind of AI blackboard system or AI integrating control programme – to engage with other systems in any potential weapon use to conform to the legal requirements and policy constraints captured in rules of engagement for specific conflicts. Crucially, under current and foreseeable technological developments, in the UK's political environment at least, some degree of human involvement will likely be a necessary part of weapon use. Elsewhere, Morgan has helpfully set out a number of ways in which AI approaches might benefit or impact upon air power.<sup>37</sup> For now, however, discussion moves on to the *system* considerations in AWS.

### **Putting the 'system' into Autonomous Weapon System**

One of the most immediate challenges militaries and governments face in attempting to operationalise AWS is to conceptualise what the system would comprise and how it would work. Part of the difficulty is that, if my experiences in numerous conferences and symposia are an indicator, many civilian experts in the multifarious domains that are needed if legal, ethical and operationally useful AWS are to be achieved, seem unaware of even basic operational requirements if, say, an air force wanted to deploy an armed autonomous aircraft. Marra and McNeil illustrate this disjuncture between theory and practice in their paper, 'Understanding the "Loop": Regulating the next generation of war machines', where they state:

As drones develop greater autonomy, however, humans will increasingly be "out of the loop." Human operators will not be necessary to decide when a drone (or perhaps a swarm

of microscopic drones) takes off, where it goes, how it acts, what it looks for, and with whom it shares what it finds.<sup>38</sup>

When Marra and McNeil claim here that humans will not be necessary to decide when a military drone takes off, where and how it operates, and what it does with the data it collects, there appears to be a disconnect from the practicalities of how advanced air forces operate and how they might incorporate autonomous aircraft/drones over time. Some basic practical assumptions need to be made for effective theorising and planning. So this paper assumes that any large future military armed drone, or LAAS, will operate – at least for a decades-long transition period – alongside manned aircraft.<sup>39</sup> Further, among many other requirements they will also need the following: hangars for storage and where repairs and servicing will be carried out; to share a dispersal, or airfield hard-standing, with manned aircraft; for armourers to still fit missiles and bombs under the wings; engineers to maintain the hardware, software, airframe, avionics, and sensors; and that their take-offs and landings will be integrated with the movements of manned aircraft and still be subject to an air traffic control system using detect-and-avoid technology. All of that just to get in the air and fly around without accidentally colliding with manned aircraft – or other LAAS – in the sky, and before integration with a Combined Air Operations Command, Defence Intelligence, air battle managers (or future equivalents), Joint Terminal Attack Controllers, and more. The most realistic scenario envisaged here for the MQ-9's successors is for elements of its systems, or functions of the humans mentioned above, to be increasingly replaced with AI over time. A long time.

Taking the RAF's MQ-9 Reaper RPAS as an approximate template for now, the 'system' operates on two levels. First, at the higher level, the RPAS sits within a much larger system – the political-military complex itself. That system sits within a clear command hierarchy which is operationally and ethically accountable for the conduct of war. Second, the RPAS is an operational 'system', comprising airframe, avionics, multiple sensors, computing, communication, information, weapon, and human elements.

British WWII bombing command hierarchy	UK Reaper MQ-9 RPAS command hierarchy	Theoretical Autonomous Weapon System command hierarchy
<ol style="list-style-type: none"> <li>1. Prime Minister</li> <li>2. Defence Minister</li> <li>3. Chairman of the Chiefs of Staff Committee</li> <li>4. Chief of the Air Staff</li> <li>5. AOC-in-C Bomber Command</li> <li>6. Bomber squadron commanders</li> <li>7. Bomber captain</li> </ol>	<ol style="list-style-type: none"> <li>1. Prime Minister</li> <li>2. Defence Minister</li> <li>3. Chief of Defence Staff</li> <li>4. Chief of the Air Staff</li> <li>5. AOC 1 Group</li> <li>6. Reaper RPAS squadron commanders</li> <li>7. Reaper captain (with continuous remote access to multiple support elements and resources)</li> </ol>	<ol style="list-style-type: none"> <li>1. Prime Minister</li> <li>2. Defence Minister</li> <li>3. Chief of Defence Staff</li> <li>4. Chief of the Air Staff</li> <li>5. AOC 1 Group</li> <li>6. Lethal Autonomous Aircraft System squadron/military commanders</li> <li>7. Lethal Autonomous Aircraft System – offensive and/or countermeasures (plus constellation of ethically implicated actors)</li> </ol>

Table 2

Table 2 compares simplified versions of a World War II bomber command hierarchy, a current Reaper RPAS hierarchy, and a projected hierarchy for a LAAS. Each hierarchy is responsible, ethically and legally, for operational decision-making, with those near the top of the hierarchy bearing greater responsibility than those at the bottom.<sup>40</sup>

The autonomous weapon, say a lethal autonomous aircraft (or autonomous weaponised drone), will not be able to function on its own outside a 'system' that includes human elements. Politicians and commanders will still decide when and how they should be deployed; lawyers and others will still advise on ROE; coders will need to write programmes and update systems. Even if autonomous machine elements of the 'system' increasingly replace human elements over time, political, legal and ethical concerns – in responsible states – will always require a degree of human input as well as human accountability; accountability for deploying the system and accountability for the component parts of AWS.

### **Communications Assurance in quantum communications**

(With contribution from Benjamin Davies, Theoretical Physicist, Loughborough University)<sup>41</sup>

Rapidly approaching from the technological horizon is quantum communications (QComms).<sup>42</sup> QComms work on the relationship between entangled photons. If two photons are entangled, measurement of the properties of one of them – say spin direction – has a direct effect on the properties of the other, entangled photon. This is true regardless of the distance between the photons. In a recent experiment, a video conference – via satellite – using QComms between Beijing and Vienna confirmed this technique.<sup>43</sup> While there is still much to be understood about the science and application of quantum technology, one major advantage it will offer is that such a system is substantially more secure from hacking, in the sense of an aggressor taking control of the system. Attempts to intercept the signal, however, would affect the quantum relationship between the photons and make QComms impossible, essentially a denial of service (DoS). In the event of such a potential signal interception, one benefit of QComms is that no information would be revealed to the eavesdropper.

In a contested environment, such a DoS could be sufficient to remove the capability of an autonomous weapon to communicate with human elements in the system. While independence of decision and action in such an environment would be part of the *raison d'être* for autonomous weapons, there are numerous reasons for wanting to retain a live comms link with the rest of the system: intelligence updates, revised ROE, system checks or the passing of other important information. Dual communication – classical and quantum – would provide the greatest possibility of maintaining communication between a LAAS and its command structure. They could be used for different functions or to provide redundancy. For example, a mission directive (or change of directive) could be sent using QComms, with standard encrypted comms providing further intelligence data. In this case, a DoS attack on the QComms would not provide an eavesdropper with the mission

information and any intercepted, classically encrypted information would be potentially useless, even if decrypted, due to that lack of mission information.

An AWS might not be immediately aware that its signal is being intercepted. A QComms system works on the basis of statistics and, potentially, there could be a delay while the AWS works out that the statistics are incorrect. Randomness sometimes matches expectations, which could result in false information being fed into the system even if it eventually shuts down. An attacker would not gain control in the same way as they would with hacking but there could be unforeseen effects. Consequently, a QComms channel may not be reliable enough to trust for immediate confirmation/refusal of a strike if there is a possibility of randomly-generated, false commands.

## **Bias avoidance in AWS**

A significant challenge for operationalizing AI in AWS is the propensity for human bias to be programmed – inadvertently or otherwise – into its component algorithms. There are therefore two linked tasks: understanding the nature and potential for human bias; and coding in such a way as to avoid inputting that bias into an AWS. Such bias could have serious repercussions when distinguishing, for example, between combatants and noncombatants, or even in making judgements about the legitimacy of AWS in the first place.

### **Human bias**

Perhaps the greatest bias that a person might have – if they are even aware of the human propensity for bias – is a sense that it does not affect them, that their own rationality can keep bias at bay. When it comes to AWS, bias operates on different levels: at a policy level there is the question of whether they should be allowed to exist, while at an operational level there are questions about how they can be used in ethical ways. Almost 50 years ago, Tversky and Kahneman described how bias in imagining the unknown can inform the extent to which an activity might be perceived as risky:

The risk involved in an adventurous expedition, for example, is evaluated by imagining contingencies with which the expedition is not equipped to cope. If many such difficulties are vividly portrayed, the expedition can be made to appear exceedingly dangerous...Conversely, the risk involved in an undertaking may be grossly underestimated if some possible dangers are either difficult to conceive, or simply do not come to mind.<sup>44</sup>

Consider these words in the context of potentially building and operating an AWS. Discussion around AWS necessarily involves imagination because future systems that are being conceived and developed do not exist yet, even though the legal, ethical and operational challenges must be considered during the ongoing developmental process. Take two possible opposed views. On the one hand there is implacable opposition to AWS, where they are 'made to appear exceedingly dangerous';<sup>45</sup> drawing on science fiction tropes

and imaginings that are informed by films like *Terminator* and *I-Robot*. On the other hand, technical experts and experienced military figures might be less concerned about the potential of AWS, perhaps because 'some possible dangers are either difficult to conceive, or simply do not come to mind' as a result of familiarity with the use of lethal force in a military context and the multiple legal and practical constraints that they operate within.<sup>46</sup> It seems highly unlikely that either position, as they have been exaggerated here, is without bias.

### Coding bias

When it comes to using AWS, bias has the potential to surface in different guises. One potential widespread risk is that the subjective bias of the coder is somehow encoded into the system through the particular lines of code that are used as the building blocks of the autonomous elements of the system. As long ago as 1996, Friedman and Nissenbaum highlighted three different categories of bias in computer systems: 'preexisting bias, technical bias, and emergent bias. Preexisting bias has its roots in social institutions, practices, and attitudes. Technical bias arises from technical constraints or considerations. Emergent bias arises in a context of use.'<sup>47</sup> Each of these types of bias is a field of study on its own, so consider the implications for AWS if coding bias was to influence their operations.

Clark observes that 'complete independence in an entity requires a structure that is free of any implicit design objectives or behavioral biases that might influence the definition or pursuit of goals.'<sup>48</sup> One of the potential challenges of AWS is the adoption of sensor systems that have different degrees of recognition effectiveness across different age, gender and racial characteristics. Introna and Wood point out algorithms that display evidence of bias in facial recognition: males being more accurately recognised than females, and older people being easier to recognise than young people.<sup>49</sup> Introna and Wood were developing the work of Givens et al, whose study found that Asians, African Americans and 'other race members are [all] easier to recognise than whites'.<sup>50</sup> Even setting aside additional practical difficulties like face coverings and the wearing of spectacles, there are clear ethical consequences for the potential uses of AWS and the identification of targets if the reliability of facial recognition is greater in some parts of the world than in others. In an assessment of the Metropolitan Police Service's (MPS) trial of Live Facial Recognition (LFR) technology in London, Fussey and Murray highlighted failures and potential risks in the system which have implications for AWS.<sup>51</sup> Watchlist accuracy poses such a risk, for example where the system correctly identifies a person on the list but for a minor offence which would not normally be deemed serious enough to warrant a place on the watchlist in the first place.<sup>52</sup> This may have an impact on the liberty of a criminal in London but the consequences are potentially more lethal for anyone on a watchlist to be targeted by an AWS. Even more problematic is accuracy of the system in recognising faces: 'Across the six test deployments MPS officers engaged with 22 individuals as a direct result of a computer generated match judged to be credible by a human operator. Fourteen of these (63.64%) were verified incorrect matches, eight were verified correct matches (36.36%).'<sup>53</sup>



Raising further ethical questions about using AI to identify human targets in an AWS, an AI system used by American judges to predict if an offender is likely to reoffend in the future is alleged to be biased towards minorities: 'The formula was particularly likely to falsely flag black defendants as future criminals, wrongly labeling them this way at almost twice the rate as white defendants.'<sup>54</sup> Transposing this degree of potential bias into an intelligence gathering context has obvious risks in terms of ensuring that individuals are not wrongly criminalised or targeted. Even if a misidentification was recognised and cancelled as part of the process of positively identifying targets, any such errors in an AI system would create and increase time inefficiency.

### **Predictability of the AI 'black box'**

Given all of the preceding complexities, this final section examines another of the significant difficulties in creating and deploying an AWS which incorporates self-learning AI algorithms. Namely, that AI – especially where a deep learning or self-learning characteristic is included – is often seen as an unpredictable 'black box'. It is possible to see inputs and outputs but not fully understand – or be able to replicate – the AI decision-making process in between. Importantly, if data is entered into an AI programme or an interlinked family of AI programmes, the output, or decision, from that programme needs to be understood and predictable if the weapon system is to conform reliably to ROE and international law. A reliable degree of predictability would, however, at least be able to engender a degree of trust that the system would function in a militarily consistent way. One difficulty presented by AI is reverse-engineering any 'black box neural networks',<sup>55</sup> or auditing an outcome to see what decisions the AI programme(s) made at every decision point along the way from the moment of the inputs. Bathaee, describes two different reasons for the inability of humans – currently – to understand the AI black box:

First, a lack of transparency may arise from the complexity of the algorithm's structure, such as with a deep neural network, which consists of thousands of artificial neurons working together in a diffuse way to solve a problem... Second, the lack of transparency may arise because the AI is using a machine-learning algorithm that relies on geometric relationships that humans cannot visualize, such as with support vector machines. This reason for AI being a black box is referred to as 'dimensionality'.<sup>56</sup>

This 'complexity' and 'dimensionality' may eventually be understood but these technical challenges do not excuse a government or military force from their ethical and legal responsibilities with regard to weapons and their use. One operational-level purpose of conducting weapon reviews in accordance with Article 36 of 1977 Additional Protocol 1 to the Geneva Conventions is to provide military commanders with the assurance that their use of specific weapons and weapon systems is lawful.<sup>57</sup> In addition, Doshi-Velez, Finale and Kortz et al have considered a number of ways to legally hold AI systems to account, from which some implications for AWS emerge.<sup>58</sup>

Considerations for Approaches for Holding AIs Accountable

Approach	Well-suited Contexts	Poorly-suited Contexts
Theoretical Guarantees	Situations in which both the problem and the solution can be fully formalized (gold, standard, for such cases)	Any situation that cannot be sufficiently formalized (most cases)
Statistical evidence	Problems in which outcomes can be completely formalized, and we take a strict liability view; problems where we can wait to see some negative outcomes happen so as to measure them	Situations where the objective cannot be fully formalized in advance
Explanation	Problems that are incompletely specified, where the objectives are not clear and inputs might be erroneous	Situations in which other forms of accountability are not possible

Table 3<sup>59</sup>

While they suggest a number of tools for ‘increasing accountability in AI systems’ – theoretical, statistical and explanation – the one that they put forward as most practical is ‘explanation’. Given the complexity of AI approaches, even explanation has limitations, although they argue that ‘[b]y exposing the logic behind a decision, explanation can be used to prevent errors and increase trust. Explanations can also be used to ascertain whether certain criteria were used appropriately or inappropriately in case of a dispute.’<sup>60</sup> Just as military commanders, RPAS operators and others today need to provide explanations for decisions they make surrounding missile or bomb strikes, future weapon strikes by AWS would require the same accountability. The discussion then becomes about the degree of explanation necessary. Humans are currently not required to explain the neural processes they used (which probably cannot be fully explained anyway) to underpin decisions to approve or conduct a lethal strike. They do, however, need to be consistent and provide enough explanation of the context as they perceive it and how they applied legal considerations in deciding a particular course of action for accountability to be served. So the *degree and nature* of explanation required of an AWS needs to be considered as technology develops.<sup>61</sup>

Moving away from law, from a deontological (rule-based) ethics perspective, a commander needs to have confidence that an AWS is capable of conforming to multiple rules and processes, including IHL, ROE, air battle management systems and air traffic control. Within these various rules and codes, the system will also need to be able to discern whether a particular use of force is proportionate, discriminate, militarily necessary and not likely to inflict outcomes or harms that are *mala in se* – evil in itself. That is, to also consider a consequentialist (or outcomes-orientated) perspective as well. However, Western Just War ethics does not merely provide a rigid set of rules. As Elshtain argues, ‘Just war thinkers do not propound immutable rules – they are not, to repeat, deontologists – so much as clarify the

circumstances that justify a state's going to war'.<sup>62</sup> Just War ethics also clarify the circumstance, means and methods of engaging in warfare, and can be extended to autonomous weapon systems. While military commanders and other combatants will necessarily be required to conform to the law and the question: 'Is this action legal?' I suggest that it will be a rare individual who, when using lethal force in war, does not also consider the associated ethical question, 'Is it right?'

But if ethical considerations go beyond the observation of rules, codes and obligations, then outcomes are the other key element. From a consequentialist (outcome-based) ethical perspective, the results of a particular action or strike are paramount. There is little point in deploying a system which, with the uncertainty of war and the capacity for things to go wrong even in the most favourable of circumstances, still leads to an unwanted, harmful, unethical outcome. The programmed or AI elements of the system can still have unintended negative ethical repercussions. Maner observes that 'the smallest possible perturbations – i.e., changes of a single bit – can have the most drastic consequences... [and] gives rise to a unique ethical difficulty, at least for those who espouse a consequentialist view of ethics'.<sup>63</sup> He goes on to describe how a single missing hyphen in a line of code caused the destruction of an Atlas Agena rocket and, with it, a Venus probe. Perhaps self-learning algorithms will learn to self-correct, or perhaps control programmes will protect against such errors or unintended outcomes, but the ethical, legal and operational consequences of coding errors or oversights cannot be avoided.

A more recent, less costly, but higher profile example of an AI self-learning algorithm learning the 'wrong' things is Microsoft's 'Tay' chatbot. Released in 2016, the purpose of publicly releasing Tay to engage with the public over the internet was partly about Tay learning to understand millennials and their language and culture, and partly so Microsoft could learn how such a self-learning algorithm performed.<sup>64</sup> What Tay learned was to be racist and genocidal, before being taken offline 24 hours later. Tay was put under a sustained attack – a form of denial-of-service attack – from trolls who subverted the original Microsoft intention. Tay's successor, Zo, has been released with a number of controls in place to prevent a recurrence of pro-Hitler sentiments and other offensive views. One criticism, however, is that Zo is now *too constrained* and 'politically correct'.<sup>65</sup> While Zo might not make racist statements like Tay, the self-learning element of the AI is limited by control functions. The ability to limit more complex self-learning AI in this way will be important for autonomous weapons, but the limitations may well be too constricting to achieve the effects that militaries desire.

## Summary

The challenge of creating a predictable, militarily effective AWS which conforms to both ethical and legal requirements is vast. Functional decision-making in AI programmes – and therefore decisions in the machine element of AWS – is not underpinned by the consciousness, cultural embeddedness, motivations, conscience, self-reflexivity and other elements of human essence that inform ethical choices. That functional decision-making in AWS is shaped by the

humans who set the context for the coding and especially those who carry it out, as well as the programming process which has its own ethical consequences. It is the human element in the autonomous weapon *system* that provides the possibility of those systems making decisions with an ethical dimension. Despite the lack of clarity on definitions, the UK has at least indicated one possible direction in the debate and in the practical development of autonomous weapon systems: 'The UK believes that the level, nature and primacy of human control over specific functions is the key consideration in the LAWS debate rather than technology, which is likely to change rapidly'.<sup>66</sup> In light of the foregoing discussion of technical, human, operational, legal, ethical and political factors, this paper concludes by proposing the following outline ethics framework for AWS, which includes *jus ad bellum*, *jus in bello* and *jus post bellum* considerations.

## **An Ethics Framework for Autonomous Weapon Systems<sup>67</sup>**

### **Section 1: Guiding ethical principles on the use of Autonomous Weapon Systems**

1. There is an ethical requirement to ensure that international law is applied to all weapon systems, including the development, use and disposal of autonomous weapon systems (AWS).
2. The motives and methods by which AWS are designed and deployed should be governed by ethical principles as set out below.
  - a. AWS should be deployed in support of the *jus ad bellum* principle that war is waged in order to obtain just peace and security, as set out in the UN Charter (1945).
  - b. War ethics permits the minimum force necessary to achieve legitimate military goals, and requires that AWS be used within an ethics framework.
  - c. AWS ethics demand the discriminate and proportionate use of force in pursuit of militarily necessary objectives.
  - d. As weapons of war, AWS which are capable of the proportionate and discriminate use of lethal force in line with international law, and are designed and deployed to achieve both, are not inherently unethical.
3. Wars should be fought only when necessary. AWS should be used in support of the *jus ad bellum* principles of last resort and military necessity.
4. AWS should conform to the principle that suffering in war should be minimised where possible.
5. Ethics of war require that judgements be made on the relative goods and harms of deploying AWS and is a *comparative* justice.
6. AWS ethics recognises the principle of asymmetry, which has been the strategic and tactical aim of military commanders throughout history. Asymmetry is ethically neutral; it is in the means of deploying asymmetric advantage that ethical judgements are required.
7. Asymmetric disadvantage with respect to AWS does not confer the right to ignore the requirement for ethical conduct and decision-making in war.
8. AWS violence, like that of fully human controlled weapons, is not inherently or necessarily a moral wrong.
  - a. Under certain circumstances, AWS violence – including killing – can be a moral

- necessity if its use results in less harm than would occur without its use.
- b. The harms caused by AWS violence may be offset by the good accomplished on behalf of others.
- 9. These guiding principles recognise and value the rights and dignity of every person.
  - a. In deciding whether or not to deploy AWS, states should consider the impact of their use, or non-use, on individual human dignity.
  - b. AWS should not be deployed where their use is expected, on balance, to cause greater loss of human dignity than would occur if they were not used.

## Section 2: Human responsibility for Autonomous Weapon Systems

1. Humans are required to retain ethical responsibility and accountability for AWS at every stage of the weapon life cycle, from design to decommissioning. Ethical responsibility or AWS extends beyond the operational chain of command to enabling parties which include, but are not limited to, designers, engineers, software programmers, AI developers, military and security intelligence personnel, scientists and weapons manufacturers.
2. Where AWS incorporate any self-learning AI or combination of AI techniques, the individual AI elements and collective AI network should be constrained by rules embedded in the AI knowledge systems. It should be possible to vary the ratio of human-to-machine functioning in AWS according to operational context and ROE.
3. Self-learning algorithms in AWS must not have the ability to change sides in any conflict. Responsibility for AWS must remain with the deploying state.
  - a. States which export AWS must ensure that purchasing states have the capability and intent to assure system integrity and legal and ethical practice.
  - b. Notwithstanding the principle that autonomous elements of AWS must not have the decision-making capacity to change sides, AWS should have the capacity and authority to intervene with lethal force to protect civilians from deliberate attack by 'friendly' or allied forces.
4. AWS should be capable of recognising *hors de combat* human targets and acting in accordance with relevant delegated legal and operational authority.
5. 'Intention' is central to the doctrine of double-effect, which plays a crucial role in the defence or criticism of civilian deaths and 'collateral damage' during military operations.
  - a. Artificial Intelligence and robotic elements within AWS should not be attributed with the capacity for conscious intent.
  - b. 'Intention' in the application of lethal force remains the domain of the human operators and chain of command which deploy AWS.
6. AWS should be used proportionately and in a discriminating manner against specified and identified targets.
7. AWS should not be used against geographical areas containing unidentified human targets.
8. Positive identification of human targets required to be confirmed in AWS 'kill chain', comprising suitably qualified elements.

9. A Final Authority Officer is required to approve each AWS mission. That authorizing officer must confirm that suitable safety checks have been conducted on each LAWS prior to each mission. Primary approval for each of these individual elements can be granted by the specialists concerned before overall final mission authority is granted.
  - a. In multinational operations, a National Asset Authority is required in order to retain state responsibility for the deployment of AWS.
10. AWS should be predictable to the extent that the deploying state can have the reasonable certainty that its operational intent will be carried out. The AWS should not have the capacity to override or ignore its programmed function or embedded operational commands. A human is required to make such changes to operational parameters and functions.

### **Section 3: Autonomous Weapon Systems and the methods and means of war**

1. State representatives are responsible for ensuring that the development, testing, acquisition and deployment of AWS conforms to international law at every stage.
2. AWS should not employ methods or means that are *mala in se*. These include:
  - a. Munitions or actions that are intended to inflict unnecessary suffering on human beings or cause unnecessary harm to the natural environment.
  - b. Deployment of munitions that are indiscriminate in nature.
  - c. Deliberate abdication or concealment of human responsibility for AWS.
3. As well as conforming to international law, the methods and means of AWS should conform to the following ethical principles:
  - a. Force must be used proportionately in relation to the importance of any military objective.
  - b. Discrimination between legitimate targets and protected people and objects, in both weapon mode and surveillance mode.
  - c. The basic humanity and dignity of people is not a legitimate target.
  - d. AWS should be deployed against targets within the concept of military necessity.
  - e. Where AWS can vary the ratio of human-to-machine input, that ratio will be guided by military necessity and Rules of Engagement.
4. AWS must, with reasonable certainty, be capable of positive identification of prohibited civilian targets such as schools, hospitals and places of religious worship.
5. AWS should be used only against identified and legitimate targets, either human or objects. They should not be targeted against geographical areas or civilian populations.
  - a. In a theatre of operations, AWS must be able to distinguish civilian criminal actions from martial actions, with authorised military force being used only against the latter.
6. The default operational requirement for AWS should be 'zero civilian casualties' unless a State approves a higher permissible civilian casualty level consistent with legal advice, rules of engagement and approval from a suitable operational commander.
7. In defence-of-friendly-forces engagements which may incur civilian casualties, a human with appropriate delegated authority must be actively involved in setting collateral damage and civilian death parameters.

## Section 4: Risk assessment and mitigation measures for AWS

1. Ethical use of AWS requires that states incorporate risk assessment and mitigation measures at every stage of a weapon life cycle. These include:
  - a. Developing the concepts and doctrines that frame AWS requirements and aims.
  - b. Design and manufacture of AWS should recognise and incorporate the ethical requirement to protect civilians in times of war.
  - c. Reliability, assurance and security of both hardware and software underpins accountability and reliability of AWS. Where multiple AI techniques are used within AWS, each individual technique and the integrating control programme must each be reliable, assured and secure.
  - d. Testing of new systems in such a way as to conform to IHL prior to being declared operational.
  - e. AWS deployed in operational theatres should be used proportionately and discriminately.
  - f. Maintenance and upgrading of hardware and software should be coordinated and controlled by humans. The AI within AWS should be limited through control functions, in the extent to which it can self-upgrade any aspect of its capabilities.
  - g. Ethical decommissioning of AWS requires that noxious substances are disposed of in such a way as to minimise risk to humans. Hardware should be recycled appropriately in a way that will not harm the natural world. All lines of computer code must be destroyed and made irretrievable.
2. AWS should be able to assess, mitigate or avoid harm to the natural environment.
3. AWS are not to cause harm to the natural environment which are long-term, widespread or severe.
4. AWS should have active safety systems:
  - a. A fail-safe manual override should be installed in all AWS.
  - b. Airborne AWS should operate an automated fail-safe Return-to-Home system where possible.
  - c. Maritime and land-based AWS should be capable of safe shut-down where malfunction could cause the untargeted release of munitions.
5. System security should be highly assured to prevent hostile acquisition or control of AWS by unauthorised persons, groups or states.
6. In pre-planned operations, the speed and volume of information provided to authorised personnel to approve a lethal strike against a human target should not exceed the capacity of the decision-maker to make a reasonable assessment and subsequent decision.
7. In self-defence reactive operations, the parameters for speed and lethality of AWS response will be set in accordance with national rules of engagement.

## Notes

<sup>1</sup> For brevity, this paper refers to 'Autonomous Weapon System (AWS)'; the term used at the 2014 ICRC Expert Meeting on Autonomous Weapon Systems in which I participated. The term

'Lethal Autonomous Weapon System (LAWS)' is preferred by the United Nations Group of Governmental Experts and elsewhere. I assume here that an autonomous weapon system is intended to be lethal.

<sup>2</sup> International Committee of the Red Cross, 1 November 2014, 'Report on Expert Meeting on Autonomous Weapon Systems: Technical, Military, Legal and Humanitarian Aspects, Geneva, 26-28 March 2014', <https://www.icrc.org/en/document/report-icrc-meeting-autonomous-weapon-systems-26-28-march-2014>, accessed 13 May 2019.

<sup>3</sup> United Nations, 23 October 2018, 'Report of the 2018 session of the Group of Governmental Experts on Emerging Technologies in the Area of Lethal Autonomous Weapons Systems', located at [https://www.unog.ch/80256EDD006B8954/\(httpAssets\)/20092911F6495FA7C125830E003F9A5B/\\$file/CCW\\_GGE.1\\_2018\\_3\\_final.pdf](https://www.unog.ch/80256EDD006B8954/(httpAssets)/20092911F6495FA7C125830E003F9A5B/$file/CCW_GGE.1_2018_3_final.pdf), accessed 10 April 2019.

<sup>4</sup> Elshatin, Jean B., 'The Third Annual Grotius Lecture: Just War and Humanitarian Intervention', *American University International Law Review*, Vol. 17, No. 1 (2001-2002), pp. 1-2.

<sup>5</sup> See Jean Bethke Elshatin, 'Just War and Humanitarian Intervention', *Ideas*, Vol. 8, No. 2 (2001) pp. 1-21.

<sup>6</sup> UK Parliamentary Debate, 17 June 2013, 'Lethal Autonomous Weapons', House of Commons Hansard, Vol. 564, Column 733, <https://hansard.parliament.uk/Commons/2013-06-17/debates/13061744000002/LethalAutonomousRobotics>, accessed 25 May 2019.

<sup>7</sup> *ibid.*, Column 735.

<sup>8</sup> *ibid.*

<sup>9</sup> International Committee of the Red Cross, 2010, 'The Geneva Conventions of 1949 and their Additional Protocols', <https://www.icrc.org/en/doc/war-and-law/treaties-customary-law/geneva-conventions/overview-geneva-conventions.htm>, accessed 2 June 2019.

<sup>10</sup> Campaign to Stop Killer Robots, 31 August 2018, 'Majority call to negotiate a new treaty', <https://www.stopkillerrobots.org/2018/08/sixthmeeting/>, accessed 15 July 2019.

<sup>11</sup> Amanda Sharkey, 'Autonomous weapons systems, killer robots and human dignity', *Ethics and Information Technology*, Vol. 21 (2019) p. 85. For further reading see Dieter Birnbacher (2016) 'Are autonomous weapon systems a threat to human dignity?' In N. Bhuta, S. Beck, R. Geiss, H. Liu, & C. Kress (Eds.), *Autonomous weapons systems: Law, ethics, policy* (Cambridge: Cambridge University Press, 2016) pp. 105-121; Ozlem Ulgen, 'Human dignity in an age of autonomous weapons: Are we in danger of losing an elementary consideration of humanity?' *European Society of International Law conference paper series*, Vol. 8, No. 9 (2016) pp. 1-19.

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<sup>13</sup> *ibid.*

<sup>14</sup> Peter Lee, 'Armed Drones: Automation, autonomy, and ethical decision-making' in Ryan Kiggins, Ed., *The Political Economy of Robots: Prospects for Peace and Prosperity in the Automated 21st Century* (Basingstoke: Palgrave Macmillan, 2017) p. 302.

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<sup>16</sup> Ministry of Defence. 2011. *Joint Doctrine Note 2/11: The UK Approach to Unmanned Aircraft Systems* (Swindon: Development, Concepts and Doctrine Centre) pp. 2-3.

<sup>17</sup> Royal Navy, 2016, 'Unmanned Warrior', <https://www.royalnavy.mod.uk/unmannedwarrior>, accessed 30 May 2019.

<sup>18</sup> MOD, 20 June 2018, 'British Army set to redefine warfare with joint Autonomous Warrior', <https://www.gov.uk/government/news/british-army-set-to-redefine-warfare-with-joint-autonomous-warrior>, accessed 20 May 2019.

<sup>19</sup> *ibid.*

<sup>20</sup> Massie, Andrew, 'Autonomy and the Future', *Strategic Studies Quarterly*, Vol. 10, No. 2 (Summer 2016) pp. 134-147.

<sup>21</sup> Birmingham Policy Commission, 'The Security Impact of Drones: Challenges and Opportunities for the UK', *Birmingham Policy Commission Report*, October 2014, p. 7.

<sup>22</sup> *ibid.*, p. 19.

<sup>23</sup> Marra William and McNeil, Sonia K., 'Understanding the Loop: Regulating the Next Generation of War Machines', *Harvard Journal of Law and Public Policy*, Vol.36 No. 3 (2013) p. 1150-1151.

<sup>24</sup> Clark, O. Grant, 'Characterization of Cyborged Ecosystems', PhD Thesis, McGill University, August 1999, p. 113-4.

<sup>25</sup> *ibid.*

<sup>26</sup> *ibid.*, p. 113.

<sup>27</sup> Human Rights Watch and the International Human Rights Clinic, *Losing Humanity: The Case against Killer Robots*, Human Rights Watch, November 2012, p.42, [www.hrw.org/sites/default/files/reports/arms1112ForUpload\\_0\\_0.pdf](http://www.hrw.org/sites/default/files/reports/arms1112ForUpload_0_0.pdf), accessed 10 June 2019.

<sup>28</sup> Birmingham Policy Commission Report, p. 66.

<sup>29</sup> Hopgood, Adrian, A., 'Artificial Intelligence: Hype or Reality?' *IEEE Computer*, Vol. 36, No. 5, p. 24.

<sup>30</sup> See Susan Fourtané, 25 August 2019, 'The Three Types of Artificial Intelligence: Understanding AI', *Interesting Engineering*, <https://interestingengineering.com/the-three-types-of-artificial-intelligence-understanding-ai>, accessed 18 September 2019.

<sup>31</sup> *ibid.*, p. 25.

<sup>32</sup> *ibid.*, p. 26.

<sup>33</sup> *ibid.*, p. 26-7. Hopgood also provides here a brief history of the evolution of blackboard systems.

<sup>34</sup> Reem Nasr, 26 March 2015, 'Autopilot: What the system can and can't do', CNBC, <https://www.cnbc.com/2015/03/26/autopilot-what-the-system-can-and-cant-do.html>, accessed 5 June 2019.

<sup>35</sup> Schmidhuber, Jürgen, 'Deep Learning in Neural Networks: An Overview', preprint, *Neural Networks*, Vol. 61 (2015) pp. 89.

<sup>36</sup> *ibid.*, p. 86.

<sup>37</sup> Morgan, Phillip, *Putting AI into Air: What is Artificial Intelligence and what it might mean for the Air Environment*.

<sup>38</sup> Marra and McNeil, 'Understanding the Loop', p. 1141-2.

<sup>39</sup> I am referring to large aircraft-sized, weapon-bearing drones like the Reaper which require a runway and not to small, hand-held or shoulder-launched drones.

<sup>40</sup> For further reading on the idea of moral hierarchy in these contexts see Peter Lee, 'Armed Drones: Automation, autonomy, and ethical decision-making' in Ryan Kiggins, Ed., *The Political Economy of Robots: Prospects for Peace and Prosperity in the Automated 21st Century* (Basingstoke: Palgrave Macmillan, 2017) pp. 291-315.

<sup>41</sup> To ensure the scientific accuracy of my references to the mysterious world of quantum communications I approached Benjamin Davies – PhD candidate in Theoretical Physics at Loughborough – to review my initial draft. With his permission, I have retained his corrections and contributions and thank him for the wording in this section. He is not responsible for the views expressed elsewhere throughout this paper.

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<sup>43</sup> Philip Ball, 'Focus: Intercontinental, Quantum-Encrypted Messaging and Video', *Physics*, Vol. 11, No. 7 (19 January 2018), <https://physics.aps.org/articles/v11/7>, accessed 1 August 2019. See also Juan Yin, Yuan Cao, Yu-Huai et al, 'Satellite-based entanglement distribution over 1200 kilometers', *Science*, Vol. 356, Issue 6343 (2017) pp. 1140-1144, DOI: 10.1126/science.aan3211, <https://science.sciencemag.org/content/356/6343/1140>, accessed 15 May 2019.

<sup>44</sup> Tversky, Amos and Kahneman, Daniel, 'Judgement Under Uncertainty: Heuristics and Biases', *Oregon Research Institute Research Bulletin*, Vol. 3, No. 1 (1973) p. 18.

<sup>45</sup> *ibid.*

<sup>46</sup> *ibid.*

<sup>47</sup> Friedman, Batya and Nissenbaum, Helen, 'Bias in Computer Systems', *ACM Transactions on Information Systems*, Vol. 14, No. 3 (July 1996) p. 332.

<sup>48</sup> Clark, 1999, p. 114.

<sup>49</sup> Introna, Lucas and Wood, David, 'Picturing algorithmic surveillance: the politics of facial recognition systems', *Surveillance & Society*, Vol. 2, No. 2/3 (2004) p. 190. <https://nbn-resolving.org/urn:nbn:de:0168-ssaoar-200675>.

<sup>50</sup> Givens, G., J.R. Beveridge, B.A. Draper and D. Bolme, (2003), 'A Statistical Assessment of Subject Factors in the PCA Recognition of Human Faces', Colorado State University, located at <http://www.cs.colostate.edu/evalfacerec/papers/csusacv03.pdf>, accessed 15 June 2019, p. 8.

<sup>51</sup> Pete Fussey and Darragh Murray, 'Independent Report on the Metropolitan Police Service's Trial of Live Facial Recognition Technology', *The Human Rights, Big Data and Technology Project*, Human Rights Centre, University of Essex (July 2019), <https://48ba3m4eh2bf2sksp43rq8kk-wpengine.netdna-ssl.com/wp-content/uploads/2019/07/London-Met-Police-Trial-of-Facial-Recognition-Tech-Report.pdf>, accessed 5 August 2019.

<sup>52</sup> *ibid.*, p. 11.

<sup>53</sup> *ibid.*, p. 75.

<sup>54</sup> Angwin, Julia; Larson, Jeff; Mattu, Surya; and Kirchner, Lauren, 'Machine Bias', 23 May 2016,

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<sup>56</sup> Bathaee, Yavar, 'The Artificial Intelligence Black Box and the Failure of Intent and Causation', *Harvard Journal of Law & Technology*, Vol. 31, No. 2 (Spring 2018) p. 901.

<sup>57</sup> Ministry of Defence, 2016, *UK Weapon Reviews*, p. 4, [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/507319/20160308-UK\\_weapon\\_reviews.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/507319/20160308-UK_weapon_reviews.pdf), accessed 12 October 2019.

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<sup>60</sup> *ibid.*, p. 2.

<sup>61</sup> *ibid.*, p. 12.

<sup>62</sup> Elshaint, 'The Third Annual Grotius Lecture', p. 6.

<sup>63</sup> Maner, William, 'Unique Ethical Problems in Information Technology', in Bynum, Terrell W., and Rogerson, Simon (Eds) *Computer Ethics and Professional Responsibility* (Oxford: Blackwell, 2004) p. 54.

<sup>64</sup> Abby Ohlheiser, 25 March 2016, 'Trolls turned Tay, Microsoft's fun millennial AI bot, into a genocidal maniac', *The Washington Post*, [https://www.washingtonpost.com/news/the-intersect/wp/2016/03/24/the-internet-turned-tay-microsofts-fun-millennial-ai-bot-into-a-genocidal-maniac/?noredirect=on&utm\\_term=.a3bc2cf8d89c](https://www.washingtonpost.com/news/the-intersect/wp/2016/03/24/the-internet-turned-tay-microsofts-fun-millennial-ai-bot-into-a-genocidal-maniac/?noredirect=on&utm_term=.a3bc2cf8d89c), accessed 16 June 2019.

<sup>65</sup> Chloe Rose Stuart-Ulin, 31 July 2018, 'Microsoft's politically correct chatbot is even worse than its racist one', *Quartz*, <https://qz.com/1340990/microsofts-politically-correct-chat-bot-is-even-worse-than-its-racist-one/>, accessed 16 June 2019.

<sup>66</sup> United Kingdom, 8 August 2018, 'Human Machine Touchpoints: The United Kingdom's perspective on human control over weapon development and targeting cycles', Submission to the Group of Governmental Experts of the High Contracting Parties to the Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May Be Deemed to Be Excessively Injurious or to Have Indiscriminate Effects, CCW/GGE.2/2018/WP.1, p. 2.

<sup>67</sup> This proposed ethics framework – like IHL – is intended to apply to states, not to individuals, groups or other non-state actors. Consideration of these elements can be added as part of a wider debate.

## Dissertation

# A New Way in War? Russian 'Hybrid' Warfare in the Ukrainian Conflict of 2014

By Flight Lieutenant Tom Raeburn

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**Biography:** Flight Lieutenant Tom Raeburn completed a Chief of the Air Staff's 'Trenchard' Fellowship at King's College London where his research focussed on strategy in Contemporary Conflicts and the structure of Violent Non-State Actors. After graduating with a Master's degree in War Studies in 2018, he is now a student pilot on the Hawk TMk2 at RAF Valley.

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**Abstract:** The speed and apparent ease of the Russian annexation of Crimea shocked Western governments. Many observers questioned whether war had evolved beyond a traditional clash of military forces. Russia appeared able to deploy a potent new range of capabilities focussing on the motivations and allegiances of populations while subordinating the role of hard military power. This article seeks to understand the Russian approach and highlight the limits of this strategy. A fusion of political, military and economic means supporting information dominance could achieve very limited aims in the grey zone between war and peace. Yet, as the situation in Eastern Ukraine would demonstrate, more ambitious aims returned war to its Clausewitzian fundamentals.

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## Introduction

The Russian annexation of Crimea caused consternation among Western observers who witnessed a rapid victory by secretive forces with hardly a shot fired. This approach relied heavily on information and media manipulation to influence the opposition, striking at the minds of the population and leaders instead of their military forces. These varied tactics fused irregular forces with strategic communications and achieved escalation dominance through the threat of a significant conventional strike. Such a fusion of effects led many to brand this intervention a realisation of 'hybrid' fourth generation warfare by a state.<sup>1</sup> This paper will first seek to understand the characteristics of hybrid warfare and their integration in Russian force development in order to analyse their subsequent application at the various stages of the Ukraine conflict. Ultimately this will demonstrate that while the fusion of Russian tactics represents a new concept of state power it cannot be classified as a new way of war. The Clausewitzian fundamentals of war remain extant as, beyond the unique regional circumstances of Crimea, territorial gains were primarily achieved by regular military force employed in decisive battles. These forces are however reinforced by a growing range of irregular and psychological capabilities exploiting the 'grey zone' where neither war nor peace are apparent.<sup>2</sup>

## The generational construct of warfare

Assessing a 'new way in war' first requires an understanding of war as a concept. Clausewitz postulated war as an act of physical force to compel the enemy to do our will - a definition which has endured in the modern world.<sup>3</sup> Yet the ways of applying this force, and its very nature, have evolved through history. The line and column tactics of early battles gave way to conflicts of fortification and concentrated firepower in the First World War which in turn were broken by manoeuvre and infiltration in the latter half of the 20th Century. William Lind, writing for the US Marine Corps, sought to cluster these forms of war into generations and suggested the world was on the verge of a fourth, decentralised, way of war where lines of conflict became increasingly blurred.<sup>4</sup> This is defined by Thomas Hammes as the use of 'all available networks - political, economic, social and military to convince the enemy's political decision makers that their goals are either unachievable or too costly for the perceived benefit'. Crucially it does not seek to defeat the enemy's military forces but instead aims directly for the political will of the enemy.<sup>5</sup>

The shoehorning of war into generations is subject to much criticism, notably for glossing over historical uses of modern tactics.<sup>6</sup> The construct of a new generation of hybrid war is however a useful frame to assess contemporary conflicts. The 2006 US National Security Strategy recognised the threat from state backed irregular forces who used unconventional methods to challenge traditional Western advantages.<sup>7</sup> Hezbollah, benefitting from Iranian technical expertise, subsequently employed a successful hybrid strategy against the Israeli Defence Force after the invasion of southern Lebanon.<sup>8</sup> This fused modern anti-armour weaponry and a strategic rocket capability with an efficient media campaign to win the battle of global opinion.<sup>9</sup> Yet it was not just non-state actors who were utilising new forms of warfare.

In 1999 two People's Liberation Army colonels published a book titled 'Unrestricted Warfare'. Here they proposed China could defeat a technologically superior opponent by employing a variety of means including economic, political and terrorism. They recognised the huge importance of modern networks and argued these could be attacked via unconventional means to defeat an aggressor economically.<sup>10</sup> This new warfare was to be underlined by various principles including: its omni-directional nature, as there would be no mental pre-conditions to setting the bounds of the battlefield; synchrony, as actions would be simultaneous and coordinated across battle-spaces and asymmetric in the use of particular capabilities to target weak points in the stronger force.<sup>11</sup> These insights frame the successful practice of hybrid warfare but further clarity is required to question a change in the way of war.

The hybrid threat is defined by Frank Hoffman as: *'any adversary that simultaneously and adaptively employs a fused mix of conventional weapons, irregular tactics, terrorism, and criminal behaviour in the battlespace to obtain their political objectives'*.<sup>12</sup> The fusion of tactics described here is perhaps the key element of hybrid warfare. Terrorism, militias and conventional force have been used for millennia but modern hybrid strategy, as defined by NATO, now seeks to deliver these in a coordinated and decisive manner such that the potential of each tactic is leveraged by their combination.<sup>13</sup> This can be contrasted with the traditional 'way' in war which seeks the coordination of regular forces on the battlefield and supports these with subordinated irregular and information capabilities.

### **The 'new' Russian approach**

Russia in the 2000s faced the dual pressures of a shrinking defence budget, which could not support the modernisation of a sprawling antiquated conventional force and the need to deter Western expansion into the Russian sphere of influence.<sup>14</sup> An operational concept which did not require extensive costly conventional capability but could realise limited political aims offered an attractive path for the military. When Sergei Shoigu became Minister of Defence in 2012 he set a new strategic direction focussed on highly trained airborne forces which could be rapidly deployed to fight a full spectrum of conflicts.<sup>15</sup> There was little revolutionary thought contained in the new force structure but it empowered military planners with a flexible professional capability supported by a new focus on information operations. Command was also centralised at the new National Defence Management Centre in order to intensify coordination between branches of the military and civilian agencies.<sup>16</sup> These developments reflected a much wider modernisation of the Russian state apparatus launched in Putin's 2012 'May Edicts'.<sup>17</sup>

The so called 'Gerasimov doctrine' has been subject to much hype in Western media and military circles.<sup>18</sup> The construct is outlined in a fiery article by General Valery Gerasimov, the Russian Chief of the General Staff, in February 2013. Gerasimov analysed recent conflicts in the Middle East and Libya to argue that the rules of war had changed as non-military means usurped conventional force to achieve political aims.<sup>19</sup> Recent Western success in Libya had effectively amalgamated precision strike, a no fly-zone nominally for humanitarian reasons

and a local militia force which Gerasimov contrasted with the poor coordination of Russian formations in the Georgia conflict of 2008.<sup>20</sup> The article recognises the potential for greater coordination of resources and new capabilities to exploit enemy weaknesses particularly in the opening stages of a conflict where war may not be declared – 'military means of a concealed character' are referenced as a key asset.<sup>21</sup> While largely focussed on the threat of Western action this updated military thought also pervaded the Kremlin with Vladislav Surkov, one of Putin's closest advisers, alluding to the obsolescence of war as a process for achieving political objectives. He argued that in a globalised world networks transcended state power and governments must therefore exploit and influence non-state groups from corporations to social networks.<sup>22</sup>

It is easy to look at the publications of military leaders and the Kremlin from 2008 onwards and conclude that Russian strategy had fundamentally changed but this would be an exaggeration of Russian thinking which has ensnared many commentators.<sup>23</sup> Much of the Gerasimov article focusses on the exploitation of hybrid tactics by NATO members and seeks to counter the threat which internal opposition could pose to Russia. This may explain a new emphasis on developing National Guard units which would be the first to face an internal revolt and possibly the centralisation of defence and security command.<sup>24</sup> Russian officials and commentators may still view hybrid warfare as a Western concept, admittedly one which has significant relevance, but do not consider it a central component in strategy. Russian doctrine, republished in 2014, places emphasis on information operations but shows little change in the method of war.<sup>25</sup> Yet when deniability is an additional tenet of hybrid warfare its exclusion from published military doctrine and the state controlled media is perhaps unsurprising.

There was no doctrinal revolution apparent prior to the Ukrainian intervention but Russian units had been trained and equipped to operate in diverse environments. No longer did Russia expect victory by defeating fielded forces with large armoured formations as both the Kremlin and General Staff recognised the potential of a leaner more agile force. The role of influence operations had taken a much higher position in the Russian order of battle and these were arguably central in the Ukrainian intervention.<sup>26</sup>

## **Prioritising communication**

Russia had assembled an impressive capacity for strategic communications prior to the Ukraine intervention. The Russian Military Academy offers an all-encompassing definition of information operations '*informatsionnaya voyna*' which can be contrasted with a much more limited tactical focus among Western nations.<sup>27</sup> Cyber activity was to be a facilitator of operations to shape perceptions of Russian activity in the pursuit of legitimacy.<sup>28</sup> Credibility was not to be the metric of success nor was selling the superiority of Russian state, instead it sought to erode 'truth' and provide a narrative to undermine Western interests.<sup>29</sup> Russian agencies specialised in developing a series of conflicting narratives which manipulated Western media and fringe political actors – anti-war stories for protest organisations, anti-LGBT for religious groups and anti-capitalist discourse for socialist parties.<sup>30</sup>

Not only had Russia developed a formidable capability in traditional media but an expanding social media presence took advantage of this new information space where false stories could be easily shared with minimal scrutiny.<sup>31</sup>

This new 'web brigade' recruited youth activists to the Kremlin Nashi organisation. Originally established in 2005 to provide 'on-tap' demonstrations in support of Russian foreign policy the group transitioned to the online arena in the late 2000s. Members were paid to post content which discredited anti-Russian media and created social media groups supportive of Putin.<sup>32</sup> A more focussed effort was conducted by the Internet Research Agency, a St Petersburg based Russian operation initiated in 2013 by a former Nashi activist. According to leaked documents the organisation is thought to have gained 600 employees by the summer of 2014 to deliver targeted content and criticism of Western government policy.<sup>33</sup> Media and diplomacy have been intrinsically linked for centuries but the expansive campaigns launched by the Russian government indicate a significant change in the practice of information operations. The role of media was expanded from simple favourable coverage of government policy to support the complex narrative of the Russian state.<sup>34</sup> As David Patrikarakos concludes in his recent book 'War in 140 Characters' the 'more doubt you can sow in people's minds about all information, the more you will weaken their propensity to recognize the truth' and this overarching goal lay at the heart of Russian propaganda.<sup>35</sup> This greatly enhanced communications capacity may not wholly represent a 'new way in war' but does indicate a major shift in the application of state power.

## **Russian influence operations focus on Ukraine**

In the months preceding the Ukraine intervention Russian coverage simultaneously attacked and discredited Western governments while exploiting new media to reach a diverse and easily influenced audience. This established the pre-conditions for intervention by shaping Western opinion and fostering nationalist sentiments among ethnic Russians residing in Ukraine.<sup>36</sup> The ferocity of Russian campaigns forced Ukraine to ban Russian broadcasters domestically but this did not prevent continued social media activity which included the 'polite people' campaign portraying extremely courteous Russian special forces entering Crimea and calling for their expansion across Ukraine. This term was picked up by many Western outlets including the Daily Telegraph and the Guardian, giving a very different veneer to what was arguably an invasion force.<sup>37</sup> Information warfare no longer relied on military actions to form the basis for favourable stories but now led the campaign in forming a favourable media environment to permit military operations.<sup>38</sup>

Russia's efforts prior to the Ukrainian intervention were not just limited to the information domain. In 2013 the government of President Yanukovich was inching towards an EU Association Agreement but faced increasing threats from Russia. These included restriction of exports and the disruption of Ukrainian industry, much of which was controlled by oligarchs with close ties to the Kremlin.<sup>39</sup> Russia offered significant financial incentives to encourage Ukraine to join the Eurasian Union and disassociate from the EU. These were



possibly combined with political blackmail as Russian intelligence officials threatened to expose government corruption and hinted at the forced annexation of Crimea.<sup>40</sup>

Reflecting on the events which led to the outbreak of the violent 'Maidan' protests Russia had deployed a limited hybrid strategy to shape public opinion, threaten government policy and ultimately achieve the political direction Moscow desired.<sup>41</sup> Yet their campaigns had been insufficient to influence the will of the Ukrainian people and Russia subsequently deployed several intelligence officers to support the heavy handed response of the Ukrainian security services.<sup>42</sup> These protests ultimately overcame the Russian sponsored government operation and succeeded in replacing the Yanukovych government with an interim administration.

### **The Crimean annexation: a hybrid success**

As the limits of psychological operations and political persuasion became apparent Russia deployed unmarked military personnel to protect pro-Russian protesters in the semi-autonomous region of Crimea. Protests were aided and led by Russian gangs, primarily the Night Wolves motor bike gang led by Alexander Zaldostanov, a close associate of Putin.<sup>43</sup> The local government had initially pledged support for the new regime in Kiev but was quickly deposed and following a questionable vote, where many representatives were being held by unidentified gunmen in the parliament building, Sergey Aksynov was conveniently elected leader. An ardent Russian supporter with alleged links to organised crime his pro-Russian party had received only 4% of the vote in the previous election – a likely indicator of significant meddling in the political process and the increasing integration of political action into Russian strategy.<sup>44</sup>

The Ukrainian government claimed an invasion had taken place, but Russia countered with an assertion their military were simply providing security patrols in the region of the Sevastopol military base. This did not claim responsibility for the hundreds of unidentified armed individuals or so called "little green men" but Russian media sought to portray their valuable role in providing security. These armed groups blocked the Ukrainian military in their bases and stifled any response by security forces.<sup>45</sup> The threat of force combined with the extensive information campaign to spread confusion and disinformation prevented any military response from Ukrainian troops.<sup>46</sup> In this permissive environment large scale conventional forces were unnecessary as vital national infrastructure could be held by small numbers of specially trained Russian forces.

Finally, the new Russian leadership sought legitimacy by winning a huge majority in a hastily organised referendum. This asked Crimean voters whether they should accede to Russia or return to the 1992 constitution of Ukraine – a vexed question giving the complexities of the latter option.<sup>47</sup>

The process of Russian annexation had taken little over a month and demonstrated a new and potent combination of capabilities. The information operations which portrayed the

Ukrainian government as fascists had fostered strong nationalist sentiment. This permissive information domain was exploited by Russian influenced networks including local political actors and gangs, who organised protests to delegitimise the national government. Hard power was delivered by a limited deployment of deniable special forces who could prevent a Ukrainian government while the hastily organised democratic process completed the process by applying a veneer of legitimacy to the new rulers. This fusion of tactics fulfils the tenets of hybrid warfare and achieved Russia's limited political objective without the need for a conventional invasion. Yet if this strategy really represents the first stage of a new way in war it must be considered in the wider context.

Russia benefited from a sprawling military base in Sevastopol and a regional majority of Russian speakers with their associated political networks. Launching an unconventional operation, they surprised a weak new Ukrainian government which had barely assumed command of the country. The historic and geographic isolation of Crimea further eased concerns of escalation and greatly complicated any response by Ukrainian forces. It must therefore be concluded that while the Crimean annexation demonstrated a new fusion of hybrid tactics it achieved a limited and comparatively easy political objective. A new 'way' in war must have wider applicability and a greater test of Russian strategy would come in the forthcoming attempt to destabilise and unseat the new Ukrainian government.

### **Eastern Ukraine and the limits of the Russian hybrid concept**

The success of the Crimean annexation combined with continued hostility to the new EU leaning government sparked pro-Russian demonstrations in Eastern areas of Ukraine centred around the cities of Donetsk and Luhansk. The Ukrainian government claimed that Russian agents were key in organising these protests which were successful in occupying several government buildings<sup>48</sup> while the gatherings were also supported by 'protest tourists' who travelled from Russia.<sup>49</sup> Ukrainian security forces were again slow to respond and by April the protesters controlled several Eastern districts.<sup>50</sup> Advancing military columns were confronted by a complex series of civilian barricades, irregular forces armed with stolen police weapons and unidentified professional troops who guarded vital infrastructure. This led to the embarrassing loss of several armoured vehicles and strengthened the separatists' credibility and military capability.<sup>51</sup>

These early successes demonstrate the epitome of a successful hybrid strategy as a large Ukrainian military force was seemingly impotent against an organised protest movement. The Ukrainian military called in fighter-bombers and attack helicopters to conduct 'shows of force' over separatist areas but with no clearly identified enemy troops they could not strike to support the armoured units stopped by civilians. Kinetic action was constrained by Russian escalation dominance as massed armoured forces stood poised to invade the separatist region given the slightest Ukrainian provocation.<sup>52</sup> Yet this seizure of territory also exposed the limits of the hybrid Russian strategy which had been effective up to this stage.<sup>53</sup>

The separatist regime secured their rule with the covert assassination of former local leaders and supporters of the Ukrainian government.<sup>54</sup> This combined with increasing use of heavy weapons eroded local support and gave the Ukrainian government a clearer mandate, and target set to prosecute with air and ground forces.<sup>55</sup> The successful counter-attacks in May 2014 regained much of the separatist region as heavy armour supported by air strikes easily defeated the poorly coordinated militias even when reinforced by Russian special forces. Russia was forced to deploy further unmarked military hardware to the region including the advanced BUK anti-aircraft system which downed a Malaysian airliner in July 2014.<sup>56</sup> Recruiting and organising proxy forces in a hybrid environment had disrupted traditional military command and greatly weakened Russian authority to control actions, particularly those which might provoke escalation and international response. The validity of these methods as a 'new way in war' must therefore be questioned given the difficulty Moscow faced in directing their effects.

Russia suffered international condemnation, economic sanctions and a further erosion of its legitimacy even when deploying its impressive media machine to claim the airliner was downed by the Ukrainian military. Yet the Russian media proved highly effective at aligning domestic opinion behind the campaign with only 3% of Russians believing the airliner had been downed by separatists.<sup>57</sup> Meanwhile extensive media efforts sought to dismantle the organisation of domestic anti-war movements.<sup>58</sup> The covert deployment of regular Russian battalions including heavy armour and artillery stopped the Ukrainian advance and allowed the separatists to solidify their frontline but the attempts at a Russian backed national revolution had failed. Sustaining the conflict was an unappetising prospect for military planners as Russia had committed almost all mobile army units to either active deniable participation in hostilities or the deterrence force held at the border.<sup>59</sup> The supposed light footprint of hybrid operations had not been realised as the conflict had reverted to traditional warfighting.

### **Traditional warfighting - an enduring concept**

The fragility of the subsequent Minsk ceasefire highlights the difficulties of the Russian hybrid concept which is reliant on irregular forces. A principal-agent problem has arisen as the Russian government seeks to match its new limited policy aims of Ukrainian destabilisation with the unlimited aspiration of the separatists to form a state and capture further Ukrainian territory.<sup>60</sup> The region now faces another 'frozen conflict' where no solution will be agreeable to the two major states while the separatists lack both the military and economic power to take an independent path. It is difficult to gauge the success of the Ukrainian intervention without a clear understanding of the Russian goals.

Andrew Monaghan in his 2017 book 'Power in Modern Russia' concludes Russia is now correcting for the 'mistake' of isolationist policies in the 1990s and early 2000s with a new strategy which will take offensive actions even in defensive scenarios.<sup>61</sup> Yet the desired vertical integration of state power is still resisted by an extensive and cumbersome bureaucracy.

It would therefore be an oversimplification to suggest that all Russian reactions to disruptive global events are from the playbook of an assiduous strategic plan.<sup>62</sup>

As Russian efforts to halt the 'Maidan' revolution failed the immediate need to secure the Sevastopol naval base was achieved via novel hybrid operations which demonstrated Russian capability and resolve to the Ukrainian government. Subsequent operations in Eastern Ukraine did not incite the desired national revolution. Instead they damaged Russian legitimacy, added costly economic sanctions and forced Russia to support a financially weak proxy state. The constant need to maintain deniability prevented Russia from applying its capable air assets and limited the control they could exert over the conflict.<sup>63</sup> Ultimately the hybrid tactics employed by Russia could not achieve the desired strategic outcomes as they constrained the employment of conventional force which might have proved decisive.

The active role of regular forces throughout the conflict undermines suggestions that the Ukrainian intervention represents an entirely 'new way in war'. Russia relied on its massed conventional forces held at the border to suppress the Ukrainian response and maintain local escalation dominance – a key element of hybrid warfare.<sup>64</sup> Subsequently as the separatists attempted to gain ground they fought a series of pitched battles against the Ukrainian army.<sup>65</sup> These battles consistently favoured the force with the greatest conventional warfighting capability and the developed structures of command and control to deploy it effectively.<sup>66</sup> Hybrid and irregular tactics proved effective in supporting protest movements in cities and confusing the Ukrainian response but could not achieve victory. In order to defeat the Ukrainian state, fighting on its own territory, regular forces were required to threaten escalation and win battles – warfare while initially supported by hybrid operations ultimately returned to traditional norms.

The underlying weakness of the Russian 'way in war' must also be viewed in the global theatre of operations. Ukraine and NATO were initially shocked by the Russian ability to conduct a fast moving deniable operation but extensive preparations have now enhanced resilience. NATO has deployed new surveillance capabilities and governments have reappraised the integration of ethnic Russians into the population thereby limiting the potential of a subversive operation.<sup>67</sup> The battles of Eastern Ukraine demonstrated the shortcomings of an irregular force when faced by organised military opposition. The NATO Enhanced Forward Presence may be insufficient to face an onslaught of Russian armour but provides the conventional capability to quickly disrupt hybrid tactics. This would ultimately escalate any attempted intervention towards a full-scale war, a wholly unappealing prospect for the Russian leadership. A 'new way in war' cannot be solely reliant on the shock of initial use and must demonstrate longer term validity. The reinforcement of the Baltic states suggests that while NATO recognises the potential of these tactics any future use could only be successful via escalation to conventional warfighting.<sup>68</sup>

The Ukraine intervention was not a revolution in the way of war. It should instead be viewed as an evolution in the employment of state power as methods diverge from traditional military means. The potential for hybrid operations had been recognised for several decades but the Ukrainian intervention represents the first significant direct employment by a nation state. There was no single radical tactic, but the fusion of capabilities fulfilled the concept of hybrid warfare by leveraging individual effects and was effective in securing the annexation of Crimea. Patrikarakos argues Russia has successfully identified and exploited the modern reality of 'grey zone'. In this new domain military victories can be secondary to the effects of 'coercive communication' on the population.<sup>69</sup> Yet the subsequent failure to achieve Ukrainian regime change and the primacy of conventional forces in battle highlight the limits of this strategy. The intervention was not therefore a 'new way in war' but highlighted the potential for a culmination of means which prioritise information dominance. These means primarily operate below the threshold of war but are nevertheless valuable in achieving limited political aims when employed in a suitable environment.

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## Commander's Perspective

# Commander's Reflections - Tornado GR Force

By Wing Commander Matt Bressani OBE and Wing Commander James Heeps

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**Biography:** Wing Commander Matt Bressani joined the RAF in 1997. Following completion of Navigator training, his operational flying career has been exclusively with the Tornado GR Force initially spanning 2001 to 2011 and, more recently, 2016 to 2019. He has completed 10 operational tours flying over Iraq, Afghanistan and Syria and completed one out-of-area deployment with 83 EAG as National Approval Authority where he cleared targets for kinetic strikes by UK aircraft. His flying career culminated when he fulfilled the role of the final Tornado Officer Commanding 31 Squadron, 'The Goldstars', where he commanded the last ever operational deployment of the aircraft.

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**Biography:** Wing Commander James Heeps was introduced to the RAF in 1996 as a Volunteer Reserve member of Cambridge University Air Squadron and began regular service in 2000. He piloted the Tornado GR4 on front-line squadrons from 2004 to 2012 and, again, as Officer Commanding IX (Bomber) Squadron from 2017 until the Tornado's retirement in March 2019. His operational experience stretches to more than 200 sorties over Iraq, Afghanistan, Libya and Syria and includes a long-range attack mounted from the UK. He currently serves as the capability manager for air-launched weapons in the Strategic Programmes Directorate of the Ministry of Defence.

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## Introduction

The Tornado GR Force (TGRF) ceased to exist at midnight on 31 March 2019, ending the service of an aircraft renowned as the bedrock of the Royal Air Force's fast-jet fleet for over one-third of the Service's existence. Having held quick reaction alert in the nuclear strike role through the latter years of the Cold War, the Tornado Force was then deployed on operations continuously but all for three weeks between 1990 and 2019. After such a lengthy commitment, it was appropriate that combat operations were sustained until 31 January 2019, just 59 days before the aircraft's withdrawal from RAF service. Wing Commanders Matt Bressani and James Heeps reflect on their commands of 31 and IX(B) Squadrons (respectively) at the culmination of this remarkable aircraft's 37 years of front-line service.

## Planning

Before discussing Tornado's final months of service, we need to go back a few years to set the scene. In mid-2014, the Tornado Force had reduced from five to three squadrons ahead of the impending termination of Operation Herrick and was planned to reduce further to two squadrons for its final five years of service. However, following the swift rise of Da'esh and the deployment of Tornados to RAF Akrotiri at the beginning of Operation Shader, the third squadron received a short-notice stay of execution (and a new number, its previous identity as II(AC) Squadron having already been assigned to a new Typhoon unit). Thus, the Force would consist of IX(B), 12(B) and 31 Squadrons until early 2018, when 12(B) Squadron would disband and leave two squadrons for the final year. There remained some uncertainty as to how long Operation Shader would endure but by late 2016, as Matt assumed command and James began his refresher on the GR4 Operational Conversion Unit's penultimate course, it seemed more and more likely to go the distance.

Such predictability aided the setting of priorities for our tenures, 'deliver Operation Shader outputs effectively and safely; release personnel for reinvestment in an under-manned Service while minimising risk to Force output and maximising retention; and take our historic squadrons and iconic aircraft out of service with due ceremony and reputations intact. From such simple objectives, many useful deductions could be drawn, and these guided the addition of detail to existing plans. We had both previously worked in the Force Headquarters, and quickly established close working relationships that set the tone for all that followed. In lockstep throughout, our alignment simplified planning and leadership tasks within the Force and management of relationships with other agencies.

## People

It is often said that 'people are our most important asset' and that 'command is about people', and sure enough a key deduction from the three priorities above was that people were central to each of them. The crucial insight was that sustaining operational flying until the end could only be delivered safely and effectively if enough personnel remained in post and were focussed on the task at hand. Averting distraction required follow-on assignments and

associated arrangements to be confirmed at the earliest possible stage. In turn, this would allow for predictable release of personnel and create time for unsatisfactory assignments to be addressed, with a view to maximising retention. Effective management of the assignment process would therefore be critical.

Notable early success came with the notification of follow-on assignments to all junior officer aircrew over two years in advance of Tornado's retirement. Their Career Manager and the Force Headquarters had been engaged from the earliest stage of drawdown planning, mapping individual aspirations against the Service need and agreeing ways ahead. Issue of assignment orders so far in advance allowed aircrew to focus fully on their Tornado duties until their individual departure dates. While some assignments were later changed as new opportunities arose and personal circumstances changed, the overall impact was hugely positive. However, with only around 70 individuals to consider, this was always going to be the simplest part of the puzzle. The big challenge facing the Force Headquarters and our squadrons would be to achieve a similar outcome for the 1,000 technicians spread across squadrons, engineering wings and bays at Royal Air Force Marham. For a variety of reasons, including uncertain manpower requirements and course availability, it would not be possible to achieve the same degree of notice that the aircrew had been given. We needed to work hard on our technicians' behalf to avoid creating a perception that aircrew were being 'looked after' at the expense of other personnel.

Royal Air Force Marham may not be every serviceperson's idea of a dream posting, but many of our personnel had strong wishes to stay, typically due to being well-established in private homes with children at school and spouses in local employment. Early on it was clear that most would be disappointed: the incoming F-35 squadrons would arrive from MCAS Beaufort fully manned, leaving only a handful of Station positions for the fortunate few. Allocation of these posts had clear potential to become a lightning rod for discontent, making transparency and firm leadership especially important in their handling.

Transparency was addressed by regular progress briefings from the Force HQ A4 Manning cell, which for some years had managed the internal allocation of TGRF engineers. Frequent workshops were held to encourage individual engagement with the assignment process and demonstrate effective use of the career preference options within the Joint Personnel Administration system. Meanwhile the squadron warrant officers spent much of their time acting as career advisers, cajoling people to consider the opportunities available in parts of the Service to which many had given little thought. SNCOs with previous multi-engine or rotary wing tours were few in number but made a valuable contribution by demystifying alternatives to the well-beaten path to the Typhoon Force.

Deputy Commander Operations set a target of a minimum of six months' notice of follow-on assignments. Next came the requirement to formulate a programme to release tranches of people from the Force, which had to be closely mapped to the operational cycle.

## Organisation

With Operation Shader showing no sign of ending, we needed to design a deployment cycle which would share the burden equitably while permitting the departure of personnel in tranches, aligned to the availability of onward assignments. Our decisions would frame the final years of the Force. If we remained as two distinct squadrons, deploying aircrew and engineers as formed units, any personnel remaining on the Force in 2019 would have accumulated substantially more separated service than those leaving earlier. The deployed squadron would also have been poorly placed to release personnel for any short-notice posting opportunities. These issues could be avoided by pooling our resources and managing individuals to optimise their time away.

We concluded that such a combined-squadron model was workable for aircrew and set about implementing it right away, with almost immediate benefit. Two short-notice opportunities for Typhoon crossovers emerged and the deployment plot was quickly reworked to release the most suitable individuals. However, we were concerned that combined working would present unwelcome supervisory difficulties for engineers, especially while deployed. Moreover, the disbandment of 12(B) Squadron provided a temporary uplift in engineer manning for our squadrons, giving us just enough flexibility to cope. The one change we made to engineering organisation was to scrap the traditional deployment rear party and its associated supervision requirements. Instead, any engineers remaining at Marham during deployments were managed by the other squadron.

## Operations

Once 12(B) Squadron had returned from its final Operation Shader deployment in mid-December 2017, we divided the remaining 14 months evenly between our squadrons. This did not mean equal blocks of time, which would have meant successive summers or Christmases away for each squadron, but it did need to be equitable overall. A major concern was the RAF100 flypast, which would have fallen during a handover/takeover period and suffered from reduced engineer availability had the squadrons not agreed to plan deployment dates around it.

Safety was a leading concern for both of us, with supervisory pitfalls waiting in abundance during drawdown to closure. Awareness of likely issues was good thanks to the excellent courses delivered by the Military Aviation Authority's Centre of Air Safety Training, and lessons from previous aircraft retirements were applied. One key lesson already highlighted was the need for everyone involved to stay focussed on the task at hand. Aircrew needed to remain prepared for Operation Shader deployments, but this needed relatively little training due to familiarity with the required skills. The Force's continuing liability for contingent operations meant that other skills could justifiably be practised, but limits needed to be set and in so doing we had to tread the line between control and empowerment. The same considerations applied to supervisory decisions affecting ground crew, for instance on fatigue management.

With morale and retention always a worry, we considered it important for our personnel to feel engaged and respected by safety management processes: in other words, not to feel disempowered by diktats from on high. Getting people to put appropriate limits on themselves was the ideal, and for the most part we succeeded through openness over our concerns and trust in our supervisors. Far from the tenuous abstract it might at first appear, our goal of protecting the heritage and reputation of our squadrons (and Force) was in fact central to the safety effort. To adapt the Burkean model of society, it emphasised the metaphorical contract between those serving, those who had gone before and those who would follow, and this would help to prevent relaxation of standards as the end approached. It was also helpful for the future of our squadron number plates to be made public as it provided additional motivation to set the bar as high as possible for our successors.

On Operation Shader, as in so many previous operations, the TGRF had very much settled into life in its deployed second home and the teams were well accustomed to delivering two pairs per day, six days per week from RAF Akrotiri. During our tenures we saw the end of the battle for Ramadi, the battles of Mosul, Raqqa and Tal Afar and, by the time of final operational sortie, there were only a few hundred metres of the Middle Euphrates River Valley in enemy hands. Hundreds of Paveway IV 500lb bombs and Dual Mode Seeker Brimstones had been employed, progressively driving ISIS from the battle.

Despite the familiarity of the domestic aspects, it would be wrong to characterise Operation Shader sorties as 'routine' and the need for leadership could emerge at any time. A change to the targeting directive during a phase of intense urban combat unsettled some aircrew, being unlike anything a generation raised on Herrick had seen. The traditional 'do your duty' approach would have been one way of responding to the unexpected leadership challenge, but an impromptu ethics seminar drawing on Staff College teachings put the issue straight to bed, at once maintaining discipline and preserving individuals' peace of mind. You never know when those academic nuggets might come in handy.

On reflection, having moved to staff roles well-removed from the front line while preparing this article, perhaps the most important reflection on Tornado's final years is the underlying reason for their success. Working sustainably, the squadrons achieved over 95% sortie dispatch rate across the last four years of service, an outstanding figure for an aircraft that had been in service for almost four decades and had once been renowned for its unreliability. To explain this, we could of course look to the quality of our teams, the quality of the support agencies, and the fact that they shared a mature understanding of Tornado built upon years of experience. While true, that alone cannot explain the broader successes described here. Fundamentally, success was due to having enough resource to complete our tasks.

Manpower was a critical aspect. In 2015 and 2016, when plans were being put in place for the final 18 months of activity, the Tornado Force HQ calculated the manning profile needed to sustain the Operation Shader deployment, convinced manpower agencies of its accuracy,

and secured resourcing to the necessary level. While career managers across the Service were typically unable to man units to 100% of standing requirements, our lower requirement could be met, and this meant that we were set up to deliver everything that was needed for our primary task in a sustainable manner.

The second critical aspect was spares. The Tornado Force had been reducing in size since 2014 and, on average, one aircraft per month was being retired and stripped of parts in the 'Reduce to Produce' programme. While this sometimes led to the disappointment of components being found 'unserviceable on fit', the shelves were generally well-stocked with Tornado spares and any delay was typically due to a part being stored elsewhere rather than being entirely unavailable (which had often been the case in earlier years).

This combination of spares availability and an appropriate level of suitably qualified and experienced personnel meant that the serviceability of Tornado during its final few years was exceptional. This was no better illustrated than during preparation for the RAF100 flypast. For weeks beforehand, IX(B) Squadron (as the non-deployed unit) had pulled work forward to ensure as much preparation as possible had been done. When the two squadrons then swapped location with only three weeks to go to the flypast on 10 July 2018, 31 Squadron arrived back at RAF Marham to find practically all of the 16 aircraft serviceable. Despite having just returned from operations and needing to take leave and fly large formation practices, the UK team was able to reach the evening before the flypast with 100% of the UK fleet serviceable and ready. It is readily acknowledged that other fleets do not have the fortune of being fully manned and certainly do not have an abundance of spares, but the Tornado experience suggests that if resourced correctly, our exceptional people will achieve what is asked of them.

## **The end of Operation Shader**

Whilst the final operational mission itself, on 31 January 2019, was the same as thousands that had gone before during Operation Shader, the feeling on the day for both of us acknowledged the fact that something was different. For everyone from the ops staff, intelligence, engineers and the aircrew, it was obvious that this was something of a momentous day: there was something almost palpable in the air. Almost two years earlier we had agreed that we would lead Tornado's final operational mission together as a crew, putting a 'Force' rather than 'squadron' stamp on the occasion. Three sorties together during the preceding week successfully headed off the expected banter about NOTAMs being needed, and on the morning of 31 January 2019 we went into the Tornado Detachment at RAF Akrotiri to fly to Iraq and Syria for the final time.

The routine was well known, we had all done it many times before, and yet even as we went to breakfast people from other detachments were wishing us luck and commenting on how big an occasion it was. This continued as we went to the Met Office for a weather brief, and on into the intelligence brief, where even though there was no new information from the previous day, everything felt a little different. Cameras were pointing and clicking at us as we walked for the

aircraft and completed our pre-flight routine. The Tornado always seemed to know when it was a big occasion, and both aircraft were ready on time and departed Akrotiri without any issues.

The mission itself was something of an anti-climax, appropriately taking in both Iraq and Syria but offering nothing more exciting than a last-minute complication on the final air-to-air-refuelling bracket. Back at RAF Akrotiri, we were welcomed by what seemed like the whole Station coming out to cheer us home. We were met at the aircraft steps by the Combined Forces Air Component Commander (US 3\*), Air Officer Commanding Number 1 Group (UK 2\*), the UK Air Component Commander (UK 1\*) and two lowly group captains. That is the only time in our careers we ever want to be met at an aircraft by such senior officers; however, they were all smiling. Phew!

## Heading Home – and the beginning of the end

After a couple of days of preparation, it was time to bring the aircraft back to the UK. We had to split the recovery over two days due to tanker capacity, with five aircraft returning on Monday 4 February; the remaining three followed a day later for a media event at RAF Marham. The Tornado Detachment block, our second home for the last few years, felt eerily quiet as we left it for the last time and once again the tension (or was it self-induced pressure?) mounted throughout the day. After some notably poor weather around the first refuelling bracket and a hydraulic failure for us to contend with on recovery to Marham, all eight aircraft had been returned at the first time of asking. Ground crew followed over the next few days and everyone from the TGRF was home by 10 February 2019. With this, the final chapter of combat operations for Tornado was complete...and then it got busy again.

The whole TGRF team had discussed for months what should be done to mark the end of Tornado and, following the example of previous retiring types, we decided upon a 'FINale'<sup>1</sup> flypast tour of UK locations associated with the aircraft. Given the size of the TGRF at its peak and the sheer number of sites involved in industrial and logistic support, the list of 'core' locations quickly swelled to over 30. Three separate routes were devised and promoted via social media. One took in the South, Southwest and South Wales; another the Midlands, North Wales and Northern England; and the third Scotland. This saw the Chief of the Air Staff, Air Chief Marshal Sir Stephen Hillier, complete his final Tornado sortie by leading the three-aircraft formation through Leuchars, Tain Range and Lossiemouth. Crews reported seeing large crowds at several of the locations, notably RAF Cosford where traffic was gridlocked for hours afterward, and the BAE Systems facility at Warton, where hundreds of staff emerged to see UK Tornados' farewell to their birthplace.

One week later, the TGRF conducted the greatest spectacle of the disbandment with a series of large formation flypasts. Thirteen of the 15 remaining aircraft were serviceable, and all 11 of the remaining crews got airborne to provide a diamond 9 formation and two (unneeded)

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<sup>1</sup>The Tornado was known informally by many in the RAF as the 'Mighty Fin' in recognition of its large tailfin.

airborne spares. Despite almost being scuppered by the late February weather, we led the formation over a graduation parade outside College Hall at RAF Cranwell before returning to Marham for three banked passes and a missing man salute. An image of the formation taxiing back was intricately choreographed, expertly captured by one of the RAF's many top-class photographers and featured in the following days' newspapers. This amazing day finished with the Hangar Party which saw around a thousand people come to Norfolk to celebrate the end of an iconic aircraft. From there the hard work was almost done: just a few sorties to keep the last remaining aircrew current all the way until the end of March (when our contingent liability formally ended) and we would be ready for the disbandment parade. Those last few sorties were the final test of the supervisory preparation carried out over many months: every crew was trusted with a 'last trip', every crew repaid the trust in full, and we were delighted that all shared our pride in the safe termination of RAF Tornado flying.

The media interest in each of these events were beyond anything we could have ever imagined, and it was testament to the two-woman Media and Comms team at RAF Marham that each event was so well covered. Genuine, open and early engagement throughout the drawdown resulted in incredibly positive results across the media channels, achieving both the aims of the Royal Air Force and supporting parties; a testament to media training and clear direction of all engaged. From photoshoots with the specially-painted aircraft, to the FINale flypast sortie on which the BBC correspondent Jonathan Beale was flown by OC IX(B) Sqn, to the thousands of hits on the OC 31 Squadron and RAF Marham Twitter accounts, to the disbandment parade, everyone seemed to want to be part of the story. It was suggested to us that the Tornado disbandment had exceeded the whole of RAF100 in terms of social media engagement, which would have been quite remarkable for such an informal effort. Whatever the truth, we were satisfied that we had done all in our power to give Tornado a fitting end to its 37 years of RAF service.

The final disbandment parade was held on 14 March 2019 in Number 1 Hangar at RAF Marham, led by Wing Commander Kevin Gatland, Chief of Staff of the Tornado GR Force Headquarters. We had the immense privilege of leading representative flights of our respective Squadrons with Air Chief Marshal Sir Stephen Hillier as reviewing officer. During his inspection he presented Operational Service Medals Iraq and Syria, without clasp, to 12 personnel. Approved by Her Majesty in February 2019, the award is made to personnel assessed as making a significant and direct operational contribution while outside the Joint Operational Area and is fitting recognition for the efforts of TGRF ground crew since the inception of Operation Shader.

During his address, Air Chief Marshal Hillier said *"Today is a time to rightly recognise the truly exceptional achievements of the people who have been the Tornado Force. We reflect on the courage, skill and commitment and sadly sacrifice of those who have been at the heart of the Tornado story, from its inception through to the present day. All have played their part to the full in the success story that is Tornado."*

## Dissertation

# Air Power Proliferation: How 'Commercial-off-the-shelf' Drones are being used by Violent Extremist Organisations to Influence The Future of Warfare in the Air

By Flight Lieutenant Peers Lyle

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**Biography:** Flight Lieutenant Peers Lyle is a trainee fast jet pilot, undergoing Advanced Flying Training at RAF Valley. He joined the RAF in July 2014, commissioning in March 2015. He completed Elementary Flying Training at RAF Wittering in April 2015, and Basic Fast Jet Training at RAF Linton-on-Ouse in May 2016. He graduated with a Master's degree in War Studies in 2018 from King's College, London, upon completion of a Chief of the Air Staff's 'Trenchard' Fellowship.

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**Abstract:** Air power, long the privilege of affluent state powers, is no longer inaccessible for Violent Extremist Organisations. 'Commercial-off-the-shelf' drones have enabled these organisations to build capabilities within the aerial domain. This is challenging the traditional dominance of air power that state powers have enjoyed and has consequences for both the forces operating on the battlefield and the within the world of air power studies. This article is a shortened version of a 15,000-word dissertation written as part of a MA in War Studies at King's College, London. The longer version is available upon request.

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## Introduction

A hundred years on from the formation of the RAF, the technical capabilities of current air forces are truly remarkable. Modern fighter jets are immeasurably advanced beyond the early aerial capabilities used during World War One, offering political leaders global strike capabilities, from thousands of feet up in the air, almost immediately. However, close to the surface, the employment of aerial assets on the battlefield is changing, and at a rapid pace. The recent conflict in Syria and Iraq has brought attention to an increasingly insidious change, and a new threat in modern warfare - Violent Extremist Organisation (VEO) use of commercially bought drones.<sup>1</sup> Predicted in 2011, John Villasenor commented;

*There will be imitators – crude at first – but better and better, and while reasonable people can disagree on how long it will take for terrorists, insurgents and other rogue groups to build or acquire weaponised drones that can be guided by video straight into a target, there is really no dispute that it is a question of when and not if. The day will come when such drones are available to almost anyone who wants them badly enough.<sup>2</sup>*

Following the proliferation of drone technology, air power, long the privilege of advance state powers, is now accessible for VEOs. 'Commercial-off-the-shelf' (COTS) drones have enabled these organisations to obtain and develop warfighting capabilities within the third dimension of the battlespace. Subsequently, nation states can no longer guarantee they own the airspace above the forces they are supporting, and this new VEO capability has already proven itself to be a deadly weapon.<sup>3</sup> As globalisation and the proliferation of ideas continues, it is likely that this capability becomes an increasingly potent threat. It is this developing situation that is the focus of this article.

This subject will be evaluated in three sections. First, the nature of COTS drones will be analysed, focusing on why and how VEOs are able to access COTS drone technology. Second, how VEOs are employing COTS drones on the battlespace will be evaluated, with regards to the four key roles of air power; Attack, ISR, Air Mobility and Control of the Air. Third, this article will offer insight in to what the employment of this new technology means for both military organisations, and within the wider discipline of air power studies.

As Dr Brian Jackson, a senior physical scientist at the Rand Corporation, identified, 'the relationship between the technology of terrorism and the technology of those fighting... [is] one of the more important modern arms races, not between superpowers in missile construction, but between small groups and states vying for the ability to either perpetrate or prevent low intensity conflict'.<sup>4</sup> Indeed, Western forces are well within an arms race in the use of COTS drone technology, and the commercial nature removes a significant element of control. H G Wells commented that 'once command of the air is obtained, the war becomes a conflict between a seeing host and one that is blind'.<sup>5</sup> However, it is the blinding of the enemy that is exactly what militaries are now struggling to do. To ignore this new capability would be a

serious error for Western forces in dealing with VEOs, and this assessment offers insight into the gravity of this new capability.

## **How and why VEOs access COTS drone technology**

Warfare is a business of survival. Whether a survival of one idea over another, or one organisation's will over their enemy, the stakes involved cannot be underestimated. Indeed, to mobilise and legitimately use destructive force cannot be a decision taken lightly, and this is often cited as a limiting factor in counter-insurgency operations for Western nations.<sup>6</sup> The aerial domain offers key advantages within warfare. Subsequently, it is unsurprising VEOs have looked to pursue aerial capabilities and use innovation to develop the potential COTS drones offer. Therefore, it is important to look at what it is about COTS drones that make them such an attractive option for VEOs.

In warfare, new technologies can very quickly alter the battlespace. It is important to highlight that whilst this article does not argue that COTS drones will have an effect on a scale seen in the past, there are two facets of this type of technology worth noting. First, the examples and techniques evaluated here are in their infancy, and history implies they will only continue to develop greater potency. Second, the age of globalisation and the unprecedented access to information would imply the rate of change is going to be steeper than in the past. As noted by Paul Scharre, 'the history of revolutions in warfare has shown they are won by those who uncover the most effective ways of using new technologies, not necessarily those who invent the technology first'.<sup>7</sup>

This section will evaluate how and why VEOs access COTS drone technology in three parts. First, it will highlight the symbolism of drone technology for VEOs as they look to grow the legitimacy of their organisations. Second, the key characteristics of COTS drones that enable their proliferation will be assessed, drawing focus to their commercial characteristics. Third, an analysis will be carried out as to how VEOs are able to source COTS drones. This will be valuable preparation for the subsequent section on how VEOs are employing such assets.

### **Symbolism of drones**

Drones hold a particular aura on the battlespace. This stems from their symbolism of the anti-terrorism campaign in the Middle East and North Africa (MENA) region, coupled to their method of air power delivery – invisible, permanent and perceptively uncontestable for the VEOs that they target. As such, to achieve even a moderate level of technical ability within this arena is a key aim of organisations looking to build their legitimacy. Western use of drones has engendered a symbolism surrounding such technology, and VEOs are exploiting this symbolism, both in the justification of their actions, and by pursuing similar capabilities.

VEOs operate in conflicts that are fought over the perception of a target audience. This applies both domestically, focusing on the support network VEOs require, and the international actors

that the organisations aim to undermine. In the fight for this perception, VEOs are using drones as more than just a physical weapon, but as a symbolic one. The heavy focus on drones in the rhetoric and propaganda realised by VEOs supports this conclusion, and by May 2017, Bellingcat had identified 121 'drone strike' propaganda videos released by ISIS.<sup>8,9</sup> The importance of credibility and legitimacy for VEOs cannot be underestimated. Indeed, 'allegiance is transferred from regime[s] to revolutionaries by shifts in the popular conception of relative credibility and legitimacy'.<sup>10</sup>

Interviews conducted by the Armament Research Services (ARES) with 'Syrian sources have indicated that there is a certain 'prestige factor' associated with operating [drones] – even small COTS models – in support of combat operations'.<sup>11</sup> Similarly, both Hamas and Hezbollah have been very vocal in their use of drones to build their legitimacy, though it should be noted, these have been both military and COTS assets. Hassan Nasrallah, the Secretary General of Hezbollah, claimed that the 'possession of such an aerial capacity [drones] is a first in the history of any resistance movement in Lebanon and the region'.<sup>12</sup> Similarly, Hamas has used drone technology to improve recruitment, with Izz al-Din al-Qassam dedicating Hamas' drone capabilities to the Palestinian Youth.<sup>13</sup> The symbolism of drone technology has not gone unnoticed by VEOs, and COTS drone technology has enabled them to engage with this characteristic.

## **The nature of COTS drones**

This article focuses on commercially available drones, and in doing so, it highlights some important characteristics and nuances of this technology, notably; cost, simplicity of operation and ease of modification – all driven by the commercial sector. The combination of such characteristics leads to COTS drones being a very effective technology for VEOs.

The commercial nature of these technologies drives the cost of accessing such capabilities down. This is vital for VEOs who have a more limited access to financial resources than the state actors they compete with, and results in COTS drones being very attractive assets for such organisations. Pablo Chovil commented that 'the value of these devices, repurposed into weapons of war, far outweighs the price paid by the insurgent and extremist organisations that wage war against state governments'.<sup>14</sup>

*Dà-Jiang Innovations (DJI)* is one of the leading companies in commercial drone technology, accounting for roughly half of the drone market share in North America in 2016.<sup>15</sup> This dominance only exists in the market for drones costing over \$500 USD, whereas below this value, 'there are hundreds of companies competing'.<sup>16</sup> As such, one is able to purchase HD-recording capable drones with remarkable capabilities for under \$200 USD. ISIS showed itself to be adapt in using both quadcopter and fixed wing drones, both easily accessible on the open market.<sup>17</sup> A 2014 propaganda video by ISIS shows the use of a *DJI Phantom* quadcopter, with live video streaming.<sup>18</sup> With a range of just under 5 kilometres, and an endurance of 30 minutes, the capabilities offered by drones of this style are disproportionately

significant compared to its cost.<sup>19</sup> Likewise, analysis later in this article will show fixed wing drones costing approximately \$200 USD (*Skyhunter FPV* and *X-8 Skywalkers*) have been used by ISIS in the ISR and Attack roles.<sup>20</sup> The minimal cost of COTS drones has enabled a wide range of actors to access of this technology, and is a key characteristic in their use by VEOs.

COTS drones are designed for the commercial user, and as such, cover a wide range of capabilities depending on the customer requirements. Furthermore, they are designed to be as simple to use as possible. Aided by miniaturised technology, the capabilities afforded to an untrained user by COTS drones is significant, and this ease of operation is a key benefit for VEOs using COTS drone technology. Driven by the highly competitive commercial market, there is a clear necessity for companies to continually improve their products. As such, the development of new technology and materials is resulting in them becoming easier to operate, and at a lower cost. Similarly, technologies that aren't designed specifically for COTS drone performance are influencing the capabilities of these assets. For 'each jump in camera technology has corresponded with a jump in COTS small [drone] capability',<sup>21</sup> from which VEOs can benefit.

There is a significant difference between procuring new technology and using such technology.<sup>22</sup> The knowledge to operate such capabilities comes in two forms; explicit and tacit, and 'it could be argued that it is tacit knowledge which makes it possible to effectively apply and use explicit knowledge'.<sup>23</sup> Whereas the employment of more complicated technology, like the incorrect use of a SA-11 system in the downing of Malaysia Airlines Flight MH17,<sup>24</sup> can have consequences far beyond those intended. The level of drone technology seen on the battlespace has resulted in capabilities that are both extremely easy to predict and employ. Modern 'plug-in-and-play' drones are simple enough that the expertise requirements for effective operation are becoming less important. Hobbyist users have demanded these requirements, and VEOs have benefitted as such. However, whilst the simple operation of drones is now easily achieved, causing the desired effects on the ground still takes a level of knowledge that offers Western forces an opportunity to negate some of the capabilities that VEOs currently enjoy.

COTS drones have shown themselves to be adapt to modification, in turn developing their capabilities significantly. Innovation and new designs have been seen worldwide, offering insights into concerning new methods that VEOs could use to employ COTS drones. The US has seen both the successful firing of a hand gun and the mounting of a flamethrower from a remotely-controlled COTS drone.<sup>25</sup> Open source information allows for other users to learn about these capabilities, including the software *OpenPilot*, that allows 'developers...[to] download the bill of materials, circuit diagram and software to build their own autopilots'.<sup>26</sup> Concerningly, ISIS documents showed evidence of over ten workshops in Mosul being used to develop drones into weaponised versions.<sup>27</sup> The ease with which these assets can be modified only adds to the attractiveness of COTS drones for VEOs.

Ultimately, COTS drones 'provide [VEOs] with advance capabilities which offer tactical flexibility without the requirement for a complex support network, making them ideal force enablers for asymmetric and 'hybrid' conflicts'.<sup>28</sup> As cheap, highly portable systems, COTS drones offer VEOs a 'distinct tactical advantage for modern asymmetric warfare'.<sup>29</sup> Such is the importance of these characteristics that Lt Gen Jack Shanahan, the US Director for Defence Intelligence, summarised 'the most important statement he could make surrounding the drone concern [was] that power, payload, endurance and autonomy of these devices are rapidly increasing while costs are rapidly decreasing'.<sup>30</sup>

## How VEOs access COTS drones

As outlined, COTS drones have certain characteristics that make the technology attractive to VEOs. However, how VEOs access COTS is of vital importance in assessing the threat it poses. Jackson commented that it is often the effects of new technology that gets attention, but the procurement of such is key.<sup>31</sup> VEO access of COTS drones will be assessed in three parts; proliferation of the technology, the spread of ideas (both driven by globalisation), and the lack of coherent international response to these organisations. For Western forces aiming to deal with this capability, preventing VEOs accessing the technology offers a method to combating the threats observed. However, in the globalised market space, it is proposed this will be very challenging.

The globalised market is an ideal environment for the proliferation of COTS technology, as global logistical chains, mass movement and worldwide communications make, by design, obtaining these technologies relatively simple. Current VEOs operate in what Rupert Smith coined as 'wars amongst the people'.<sup>32</sup> As such, intervening forces try to build stability, security and a sense of 'normality'. In doing so, the use of embargos, sanctions and preventing the movement of goods, must be carefully considered. As noted by Jackson, 'because of the economic importance of technology diffusion in the economic realm, a great deal of effort has been devoted to designing strategies to remove roadblocks to effective technology use in commercial processes and product manufacture'.<sup>33</sup> It is within this ambiguous flow of goods that COTS drones and their associated systems can slip through unnoticed. The sheer mass of global markets, which is difficult to control, makes the proliferation of COTS drone technology relatively easy. This applies to both hardware and software – as online access for drone software is developed by companies, it can easily be exploited by VEOs in their pursuit of maximising the effectiveness of their assets.

It is important to note that the effects of the globalisation are not limited to the proliferation of drone technology to VEOs. The interconnectedness that comes from the internet has allowed VEOs to access not only the technology, but also the *ideas* surrounding both their procurement, and application. This provides a method that importantly, comes with minimal risk.<sup>34</sup> Worldwide communications and the internet has led to the proliferation of ideas at a rapid rate, which, in turn, influences the employment of COTS drone technology by VEOs. Indeed, this article is focused on what is likely to be the beginning of a capability VEOs may

enjoy for many years to come, and it is likely that VEOs will try to employ this capability in future conflicts. The inspiration other actors may gain from the proliferation of ideas was highlighted by the presence of 'two drones among the material seized in the house of the militant who carried out the attack at the Reina night club in Istanbul'.<sup>35</sup> The idea that drones can provide new and effective capabilities is spreading.

Conflict Armament Research (CAR) carried out a three-year investigation into the weapons of ISIS, publishing a 200-page report in December 2017. Their findings are a stark reminder of the contradictions inherent in supplying weapons into armed conflicts in which multiple competing and overlapping non-state armed groups operate.<sup>36</sup> Indeed, focusing on the complex geopolitical situation of the MENA, there is distinct lack of coherence in the response to VEOs from international actors. This confusion is ideal for the proliferation of technologies throughout the battlespace. The porous borders surrounding the region acts as routes not only for foreign fighters, but also for equipment required to sustain the conflict. Whilst not explicitly drone technology, results from the CAR report 'underscore[d] the predominant role of the Turkish domestic market as a source of [IED] precursors'<sup>37</sup> for the conflict in Syria and Iraq. It is within this chaotic battlespace that VEOs are able to exploit their access to a globalised market, from which access to COTS drone technology is possible.

### **Conclusion**

Drones are symbolic of Western military dominance, and the employment of COTS drones by VEOs offers a way for these organisations to build legitimacy. ISIS, Hamas and Hezbollah have all paid specific attention to drone technology in their propaganda and when coupled to the innate advantages that the aerial domain offers, it is unsurprising that it has been a technology VEOs have looked to develop.

This development has been aided by some key characteristics of COTS drones. Their low cost, ease of operation and ease of modification, combine to make them an attractive new capability that VEOs are looking to exploit with minimal investment. Whilst there is a requirement for additional knowledge to maximise the effectiveness of such a capability, modern 'plug-in-and-play' designs allow for technology that is very simple to operate. This design is inherent in the commercially-driven sector, and the target audience of drone development.

The environment within which VEOs operate lends itself to the access of commercial technology. Globalisation has increased the proliferation of this technology, both on the international market and online, providing easy access to hardware, software and the inspiration required to use such technology. The technology found on the battlefield in Syria and Iraq emphasises this point, and the flow of commercial products from surrounding nations highlights the porous membrane that surrounds the current conflicts in the MENA. It is likely future VEOs will look to build on what the technology offers, and one would expect the presence of COTS drones in the battlespace to increase.

## VEO use of COTS Drones

The first recorded combat death from an ISIS operated COTS drone occurred in October 2016. A Chinese built X-8 *Skywalker*, captured by Kurdish forces, was laden with explosives. The subsequent detonation caused the death of two Kurdish soldiers, injuring a further two French Special Forces Commandos.<sup>38</sup> A simple delayed fuse, on a cheap expendable drone, showed the world a worrying new capability ISIS were looking to develop. The effects of drone capabilities used in the conflict in Syria and Iraq have been significant. Indeed, 'an Iraqi general... stated that anti-drone technology [was] their top necessity'.<sup>39</sup> The employment of COTS drones by VEOs creates capabilities that can have strategic effects far beyond the relatively simplistic tactical employment, further exacerbated by the politically fragile environment of current conflicts. They can be considered as force multipliers, amplifying the efficacy of the weapon systems already in theatre.

The Centre for the Study of the Drone (CSD) identified 38 different models of drones being used in Syria and Iraq during 2016, of which 14 were commercially available or modified such that they were unidentifiable as to their source.<sup>40</sup> This section will analyse VEO employment of COTS drone technology by investigating their capabilities with regards to the four roles of air power; Attack, ISR, Air Mobility and Control of the Air.

### Attack

VEO employment of COTS drone technology to directly attack ground targets is at a level of relative infancy compared to other capabilities. However, as drone technology develops, so too can the lethality of attacks that are carried out using them. The potential of this threat has not gone unnoticed, and previously, 'Britain's top commander in [Iraq], Major General Rupert Jones, said that ISIS were using off-the-shelf drones to drop grenades on civilian and security forces in Mosul in inhuman and indiscriminate attacks'.<sup>41</sup>

The reality of employing COTS drones to directly attack ground forces is the addition of a physical dimension to the battlespace. Whereas traditionally VEOs have been operating within a two-dimensional battlespace, employing drone technology has enabled a new route from which attack is possible. The Iraqi Security Force (ISF) led battle for Mosul against ISIS has shown some of the possibilities associated with using drones within the Attack domain. It has been assessed that 'the Mosul offensive has seen this kind of drone warfare [propaganda, ISR, Command and Control (C2)] step up a level, with ISIS employing drones armed with an assortment of different munitions, sometimes in conjunction with other assets, to deadly effect'.<sup>42</sup>

ISIS were not the first VEO to use UAS technology for direct attack within the current conflict in Syria.<sup>43,44,45,46</sup> However, ISIS have added scale to this method, and propaganda released by the group in January 2017 purports to show 20 drone strikes.<sup>47</sup> Whilst the destructive nature of drone delivered weaponry is incomparable to that delivered by Vehicle-born IEDs (VBIEDs), one of the most effective weapons used by ISIS, their employment has significant effects on

the battlespace. It is by using the combined capabilities of aerial attack and ground offensives that the attack capability of VEO COTS drones appears most effective,<sup>48</sup> and draws clear parallels with the coordinated use of Air to Ground fires and ground forces used by Western nations.

The majority of ordinance advertised in ISIS propaganda is small - modified hand grenades and 40mm shells. As such, the kinetic effects achieved by their use is fairly limited. However, there have been reports of ISIS adapting RPGs for use on drones. Evidence of this capability has been found in Deir ez-Zour, Syria,<sup>49</sup> along with reports of their use in Raqqa.<sup>50</sup> Using light munitions has the benefit that they are easily sourced in the current conflict zones, and whilst less effective than mortars, their accuracy can be greater.<sup>51</sup>

The psychological effects of aerial attack by drones is very important. Attack from an aerial threat is a new challenge from VEOs; one that has significant effect on the psyche of both personnel involved on the battlefield, and the perception of popular support required at home for Western forces to legitimise their intervention. COTS drones are quiet and can be inaudible as close as 40 metres depending on wind direction.<sup>52</sup> Once combined with the noise of combat operations, not only do VEOs have systems that may be very difficult to see, but are also effectively silent. To score kills through this method adds a significant propaganda win for VEOs, and the appreciation of such is displayed through VEO portrayal of drone capabilities in media operations.

It is worth re-iterating this technology is in its infancy and with only a small amount of imagination, further capabilities can be envisaged. Swarm attacks, with high numbers of small, weaponised drones, whilst yet to be observed being used by VEOs, could add a very potent new capability to the Attack domain for COTS drones. Indeed, in 2017, Lieutenant General Michael Lundy, Commander of the US Army Combined Arms Centre, commented that 'the use of small [drones] in Mosul right now by [ISIS]...[has] actually gone to almost swarm-level capability in a couple of cases. That is a big area [the US] are learning.'<sup>53</sup>

### **ISR**

Alexandra Sander, Research Associate with the Technology and National Security Program at the Center for a New American Security, commented that 'the ability to conduct persistent, low-cost intelligence, surveillance, reconnaissance is a well-recognised and core advantage of uninhabited systems',<sup>54</sup> and this capability has not been overlooked by VEOs. ISIS are aware of this fact, employing drones for reconnaissance against the ISF in Ramadi during 2015.<sup>55</sup> Similarly, a Turkish military detachment, based in Bashika Camp, Northern Iraq, found themselves exposed to 'intensive harassment fire 15 minutes after identifying a drone.'<sup>56</sup> The aerial view VEOs now enjoy through their employment of drones has provided greater ISR capabilities.

In providing real-time ISR, COTS drones have provided VEOs with the capability to make Indirect Fire (IDF) capabilities more effective, as well as improve the reconnaissance capabilities of targets. A crude, unsophisticated weapon system, such as an unguided mortar, can become



a significantly greater threat if employed with effective ISR. The knowledge and application of ISR to obtain accurate targeting creates a weapon with increased efficacy. This technique has been observed both by Hamas and ISIS, as 'the [latter] group continue[s] to use drones mostly for surveillance, collecting intelligence and guiding mortar, cannonball and rocket fires against static targets'.<sup>57,58</sup> Indeed, ISIS have both an 'Aviation Surveillance Sector' and an 'Airborne Operations Centre' to maximise the effectiveness with which the organisation can employ its drone technology.<sup>59</sup>

The most significant employment of UAS technology within the ISR domain has been the development of an effective C2 network. ISIS have proved very capable in this respect, highlighted by their coordination of VBIEDs. The introduction of drones was a key link to making the threat of VBIEDs an incredibly dangerous capability during Operation Conquest.<sup>60</sup> The aerial view allowed for VBIEDs to be directed around road blocks,<sup>61</sup> and using the natural cover provided by urban warfare, positioned more effectively in order to increase their lethality. With an estimated one million civilians present in Mosul during the operation, the challenge to identify a VBIED from a normal civilian vehicle was already an issue for the ISF. When coupled to the C2 network developed by ISIS, they were able to effectively employ increasingly precise targeting of the ISF through aerial surveillance,<sup>62</sup> with the capability to not only effectively target columns of Iraqi troops, but also prioritise and target the most valuable vehicle within that target set.<sup>63</sup>

The employment of VBIEDs in Eastern Mosul caused significant casualties amongst the ISF. Over 900 attacks were recorded during the efforts to liberate the city, causing 40% of Iraqi Special Forces to be injured or killed.<sup>64</sup> The increased efficacy of these very crude weapon systems was a key capability that COTS drones enabled during the fight for Mosul. The employment of COTS drones by VEOs in the ISR role offers a key capability, at a minimal cost or risk to the organisation. ISR was previously a missing link for VEOs, which using COTS, has now been partially closed.

### ***Air Mobility***

The extent to which COTS drones have been used by VEOs in the Air Mobility role has thus far been fairly limited, but there have been instances within criminal organisations where their potential has been displayed. Therefore, it is important not to ignore this capability.

As the technology develops, the Air Mobility potential of COTS drones increases. The introduction of greater autonomy, allowing drones to transport equipment with pre-loaded GPS coordinates and minimal input from any ground operator, offers VEOs a new method of smuggling equipment, finances and other assets across a battlespace. This has been observed in the operations of Mexican cartels, with COTS drones used to deliver drugs across the US-Mexico border using pre-set GPS locations. US Security Services estimate that over 150 smuggling flights were carried out in 2014 by drones across the border.<sup>65,66</sup>

More importantly, COTS drones offer a method of smuggling with minimal risk – much less so than using human traffickers. The current payloads that can be delivered are very small

compared to manned smuggling, but so too are their 'footprints' making them more elusive to security services. Future developments to COTS drones may overcome the payload limiting factor. Amazon have shown themselves to be pioneering drone delivery systems that will drive the technology to having larger payloads, with greater endurance.<sup>67</sup>

As highlighted, the Air Mobility role is limited by the technology available. Nevertheless, the use of drones for Air Mobility is moving beyond its infancy. The Syrian Airlift Project has delivered aid to Aleppo using custom made drones,<sup>68</sup> and it is likely the minimal-risk method drones offer for transporting assets will increase their use in this role by VEOs. COIN operations aim to restrict the freedom of manoeuvre of VEOs, and COTS drones offer the potential for these organisations to overcome this issue.

### **Control of the Air**

The introduction of COTS drones in to the battlespace draws focus on issues surrounding Control of the Air in warfare. In recent conflicts, Western forces have been the dominant presence among air assets present in theatre - this is no longer the case. COTS drones have challenged the assumed ownership of airspace by Western forces.

Giulio Douhet, an Italian General and air power theorist, identified the first aim in conflict was to obtain *Command of the Air*.<sup>69</sup> He defined this as the 'means to be in a position to prevent the enemy from flying, while retaining the ability to fly oneself'.<sup>70</sup> Absolute Control of the Air can, therefore, be interpreted as having complete freedom of manoeuvre of your own assets, and complete denial of manoeuvre for your enemy's air assets. With the proliferation of surface to air missiles, and the financial and political consequences of losing air assets on operations, it is rare for *complete* freedom of manoeuvre to be achieved. Indeed, during World War II, the RAF achieved *sufficient* Control of the Air to deter Hitler's desire of invading the mainland of Great Britain, but as shown by the Nazi Blitz offensive, the German Luftwaffe were still able to employ air assets over the UK. This example highlights some nuances of how Control of the Air is employed. The term has both a *geographical*, and a *temporal* dimension – localised air superiority.

The introduction of COTS drones on the battlespace has enabled VEOs to contest this idea of air superiority, as modern air forces are unable to fully control the airspace close to the ground. This article does not argue that VEO use of COTS drones will enable these organisations to contest Western air superiority in the upper airspace regions of a conflict.<sup>71</sup> However, as has been shown, COTS drones are enabling VEOs to have enjoy some of the privileges of air power in the air space close to the surface of a conflict. The ideas surrounding the traditionally assumed Western Control of the Air are being contested.

It has been commented that ISIS 'owned the sky under coalition air power'.<sup>72</sup> Indeed, 'US Central Command reported that in the last two months of 2016, ISIS drones were seen every day in Mosul. By February 2017, this had risen to 10-15 ISIS drones every day'.<sup>73</sup> Despite all the air

power in the upper airspace region, Western air forces were not able to exercise Control of the Air in the lower airspace of the conflict. This is likely to be a growing issue and as the proliferation of this technology continues, there will be greater employment of these assets in theatre by all sides involved in a conflict.

Whilst the counter-drone technologies being developed are not the focus of this article, certain issues brought about by the commercial development of these assets need to be noted. Increasing autonomy for COTS drones, having already been proven useful in the Air Mobility role, also have an effect when looking at contesting Control of the Air. Denying the use of these assets by interrupting data links only works when data links are available. With any increase in automation, the chances of interrupting the operation of COTS drones decreases – a concerning trend for the development of counter-drone technology. Similarly, increases in automation will allow for greater numbers of assets to be operated by a single user, aiding the effectiveness of the system, and offering a route to swarm-levels of capability.

Coordinated swarms of COTS drones offers a potential new method for VEOs to contest Control of the Air. A 2016 video released by the US Department of Defence shows 103 micro-drones being launched from F-18 fighters to test swarm technology.<sup>74</sup> In this sense, swarming 'refers to a number of autonomous aircraft, networked together, and working towards a common goal'.<sup>75</sup> With a wingspan of 12 inches, the microdrones were 'seen flying through the air like a swarm of high-tech bees'.<sup>76</sup> Similarly, there are examples of major companies using swarms of coordinated drones for entertainment and marketing.<sup>77</sup> Whilst this example shows coordination of drones beyond the capabilities of VEOs to date, they highlight issues that may well be prevalent in the future.

An effective coordinated swarm of micro-drones offers the potential to damage both air and ground assets in theatre - whether used as weaponised platforms in the Air to Ground role, or by swarming an area that could inhibit flight of aircraft within that airspace. With the consideration applied to the highly asymmetric cost of a swarm of low-cost COTS drones against very expensive Western air assets, it is feasible a swarm of COTS drones could effectively deny an airspace region. Although VEOs achieving overall air superiority would be doubtful, the denial of airspace to Western forces would remove a huge advantage that VEOs would otherwise have to contend with.

## **Conclusion**

VEOs have shown themselves to be adapt in using COTS drones to achieve a level of air power, without possessing an air force. Although the effectiveness of COTS drones in the Attack role is less when compared to ground fires, VEOs have used these assets to drop primitive munitions on enemy forces. In the ISR domain, COTS drones have already proven themselves as highly effective assets, providing aerial control for ground fires and a primitive C2 network for VEOs. ISIS has used the latter to improve the effectiveness of its VBIEDs, even more so when coordinated with the force dispersal effects of aerial attack. Currently, VEO use of COTS

drones in the Air Mobility role is fairly limited. However, as the technology develops, it is likely this minimal-risk method of transportation will become a useful option for VEOs. Indeed, the criminal world is using such methods frequently. The use of COTS drones by VEOs also adds complications to the assumed Control of the Air Western militaries have previously enjoyed. As technology improves, with developments in automation and swarm technology, it is possible that Western Control of the Air can be challenged further. Indeed, it is the future that will be the focal point for the last section of this analysis.

## **Future Considerations**

The introduction of COTS drones on to the battlespace offers both new challenges and opportunities. These apply to military and non-military organisations, and considering the rate of development of these assets, proactivity is key if these situations are to be exploited effectively. Kelley Saylor has argued that 'hobbyist drones are often less discussed within a security context, thought they perhaps hold the greatest potential for achieving overmatch against the [US] in the near term'.<sup>78</sup>

### ***Military Considerations***

As outlined, VEOs are able to obtain elements of air power without the need for an air force. This in turn demands a reaction from military and government organisations if they are to maintain the upper hand in this domain of warfare. The Birmingham Policy Commission commented that 'as the nature of British air defence changes, the RAF and the MOD should consider, with civil authorities, the implication of the malign use of [drone] technology by state and non-state actors'.<sup>79</sup>

For Western governments and militaries, containing COTS drone technology is not an option. The proliferation of hardware, software, and more importantly, the idea that 'drones are a game changer in the wrong hands',<sup>80</sup> means that controlling the access to this technology is not viable. Sander has argued that 'limiting the spread of this technology is neither practical nor probable with the growth of commercial drones, international sales...and increases in indigenous production'.<sup>81</sup>

Anti-drone technology needs to be cost-effective, which is particularly challenging considering the low cost of COTS drones being a key characteristic. Tamir interceptor missiles in Israel's Iron Dome cost \$100,000 USD, and it is challenging to justify their employment against a cheap drone, with unidentified intentions.<sup>82</sup> Whilst specific anti-drone techniques being developed are not the focus of this article, the release of \$226.8 million USD for counter-drone solutions by the US Department of Defence in the 2017 Financial Year implies steps are being taken in the right direction.<sup>83</sup>

In addition to anti-drone technology, education is required. The employment of COTS drones by VEOs, in hindsight, is not remarkable. COTS drone technology needed to reach a sufficient level of capability before being useful to VEOs, and it begs the question as to

whether there are other new, commercially developed technologies that could subsequently be seen on the battlefield in decades to come. The threat of COTS drones was overlooked, to the extent that Lieutenant General Stephen Townsend, Commander of Operation Inherent Resolve,<sup>84</sup> said 'the number one force protection priority in the fight against [Daesh] was to defuse drones.'<sup>85</sup> Predicting such developments will be an expensive and challenging pursuit, but a necessary endeavour if states are to maintain their asymmetrical advantage over VEOs.

The use of COTS drones on the battlefield does offer opportunities to state militaries. In the conflict between the Ukrainian Government and the Donetsk People's Republic, the Ukrainian military have used COTS drones.<sup>86</sup> Similarly, their aforementioned use by the Syrian Airlift Project offers an insight in to aid and resupply operations that COTS drones could be used for by state forces in the future. Within the idea of a modern arms race, the ISF copied ISIS's tactics, by purchasing 'their own commercially available drone[s], offering the same low-cost, crystal-clear image and user interface, and used them offensively'.<sup>87</sup> In addition, the idea of weaponising a cheap COTS drone, paired with Virtual Reality goggles to improve handling characteristics,<sup>88</sup> to create a flying weapon that ground forces can use, offers the military personnel exciting new capabilities. Learning from VEO use of COTS drones can offer fresh insights into military requirements.

### ***Theorist Considerations***

As a developing technology, being employed on a scale unseen before, the use of COTS drones is a fast moving and challenging new characteristic on the battlefield. As such, the questions it poses in the realms of air power and international law need to be considered.

In recent unrest in the Gaza Strip, Israel were recorded using an armed COTS drone to drop tear gas on Palestinian protestors.<sup>89</sup> As highlighted by Faine Greenwood et al., 'the IDF's choice to use [an *ISPR*A Cyclone – an altered version of a *DJI Octocopter*] highlights the blurring of lines between consumer and military drones, and their uncertain status under international humanitarian law'.<sup>90</sup> Indeed, 'the growing number of operators, alongside the complex legal and ethical issues raised by the use of armed drones, highlights the urgent need for clear international controls'.<sup>91</sup> As governing bodies and international law struggles to keep pace, the commercial sector is driving capabilities at a fast rate. If any oversight of COTS drones in warfare is to be possible, these developments need to be tackled soon.

It is arguable that COTS drones will be used in all conflicts in the future, and therefore such a technology deserves attention within academic study. This includes the position it holds in both conventional war and sub-conventional threshold conflicts, the implications it brings in terms of commercially sourced assets on the battlefield, and the refocusing of the moral and ethical considerations of drone use. Such analysis is required to educate and inform the debates surrounding this new technology, in order that both militaries and international bodies can counter, and in turn employ, COTS drones on the battlefield.

## Conclusion

In 2012, the Islamist Abu 'Ubayda al-Maki said;

*'With the availability of these great inventions, there is only one thing left, which is the unmanned aerial vehicle. It is the sought hope and the unachieved dream....why don't the brothers build planes like these or buy them from the market, load them with explosives and target military bases, or even develop these planes; and make them fly for longer distances? These planes can be the best supporters for mujahidin and they can [be] easily found [in] toy stores.'*<sup>92</sup>

Unfortunately for Western forces, his claim has manifested itself into reality, and the introduction of COTS drones on the battlefield has enabled VEOs to access air power without the possession of an air force. As the weaker actor on the battlefield, accessing such a new domain offers higher marginal gains to VEOs, as provides a new route to challenge Western military dominance.<sup>93</sup>

The importance of the aerial dimension in warfare is evident by the priority Western governments place on it as a method of pursuing political aims. The introduction of unmanned systems into air power has further developed the capabilities offered by air forces, but in turn, has raised challenging moral and ethical considerations in their use. Ultimately, US-led drone use against VEOs has taken on a symbolic meaning beyond its kinetic effect and this type of technology has plagued VEOs since 9/11. However, developments in the commercial technology sector have allowed VEOs to fight back.

COTS drones offer a route for VEOs to contest in the aerial dimension, and by possessing such a symbolic capability, VEOs are able to build their own credibility. As commercial products, COTS drones offer VEOs a cheap, easily accessible and simple to use asset that has benefits that easily surpass their price tags. In complex conflicts, with access to global markets and the proliferation of ideas through the internet, VEOs are able to access this game-changing technology with relative ease.

Despite the relative infancy of the technology, VEOs, have shown themselves as being able to employ COTS drones effectively on the battlefield. In both the Attack and ISR roles of air power, COTS drones have shown themselves to be have serious potential, no more so than in the ISF operation to liberate Mosul from ISIS. The criminal world has displayed possibilities COTS drones offer within the Air Mobility role, and this is something that is likely to develop as the technology capabilities improve. COTS drones have also challenged Western Control of the Air. For all the technological dominance of Western militaries, VEOs are able to contest ownership of the lower airspace region in the MENA today.

As Western governments, under fiscal constraints, look towards the future, it is important to know the seriousness of likely threats. COTS drones have already proven themselves effective

on the battlefield, and the market for such assets is rapidly growing. It is vital therefore for militaries and security forces to plan appropriately, under the pretence that VEOs already have this capability – it is too late for prevention to be the answer. Similarly, the use of commercial products on the battlefield is another contribution to the ambiguity in conflicts being fought today. Legal frameworks appear thin when applied even to military drones, and the addition of state and non-state use of COTS drones is even a step further away from the rules based international system Western governments seek to defend.

## Notes

<sup>1</sup> There are many terms used for these systems, including 'drones', 'remotely-piloted air systems' and 'unmanned aerial vehicles', with each term having its individual nuances and implications. For ease of reading, and as an acceptance of most academic as opposed to military authors, this thesis will use the term 'drone' throughout.

<sup>2</sup> Don Rassler, *Remotely Piloted Innovation: Terrorism, Drones and Supportive Technology* (West Point: US Military Academy, 2016), 63.

<sup>3</sup> Nick Waters, "Death From Above: The Drone Bombs of the Caliphate," *Bellingcat*, February 10, 2017. <https://www.bellingcat.com/news/mena/2017/02/10/death-drone-bombs-caliphate/>

<sup>4</sup> Brian Jackson, "Technology Acquisition by Terrorist Groups: Threat Assessment Informed by Lessons from Private Sector Technology Adoption," *Studies in Conflict & Terrorism* 24:3 (August 2010), 4.

<sup>5</sup> HMG, *Joint Doctrine Publication 0-30 – UK Air and Space Power 2nd Ed.* (HMSO: MOD Shrivenham, 2017), 24.

<sup>6</sup> M Smith and David Jones, *The Political Impossibility of Modern Counterinsurgency: Strategic Problems, Puzzles and Paradoxes* (New York: Columbia University Press, 2015), 169.

<sup>7</sup> Rassler, *Remotely Piloted Innovation: Terrorism, Drones and Supportive Technology*, 62.

<sup>8</sup> Larry Friese, N.R. Jenzen Jones and Michael Smallwood, "Emerging Unmanned Threats: The use of commercially available UAVs by armed non-state actors," *Armament Research Services Special Report No.2* (February 2016), 51.

<sup>9</sup> Joanna Frew, "Drone Wars: The Next Generation – An overview of new armed drone operators," *Drone Wars UK* (May 2018), 24.

<sup>10</sup> Clive Blount and Charlie Sammut, "A Gift to Our People': The Use of Drone Technology by Islamist Insurgents," *Air Power Review* Vol. 19 No. 1 (Spring 2016), 16.

<sup>11</sup> Friese, Jones and Smallwood, "Emerging Unmanned Threats: The use of commercially available UAVs by armed non-state actors," 43.

<sup>12</sup> Blount and Sammut, "A Gift to Our People': The Use of Drone Technology by Islamist Insurgents," 14.

<sup>13</sup> *ibid.*, 15.

<sup>14</sup> Pablo Chovil, "Air Superiority Under 2000 Feet: Lessons from Waging Drone Warfare against ISIL," *War on the Rocks*, May 11, 2018. <https://warontherocks.com/2018/05/air-superiority-under-2000-feet-lessons-from-waging-drone-warfare-against-isil/>.

<sup>15</sup> April Glaser, "DJI is running away with the drone market," *Recode*, April 14, 2017 <https://www.recode.net/2017/4/14/14690576/drone-market-share-growth-charts-dji-forecast>.

<sup>16</sup> *ibid.*

<sup>17</sup> A quadcopter is a 4-rotor drone, able to hover and maintain a stable geostationary position in flight.

<sup>18</sup> Dan Gettinger, "Drones Operating in Syria and Iraq," *Centre for the Study of the Drone* (December 2016), 4.

<sup>19</sup> The RRP for a *DJI Phantom 3* is under \$700 USD <http://www.argos.co.uk/product/6349772> Accessed 30 Apr 2018.

<sup>20</sup> Serkan Balkan, "Daesh's Drone Strategy – Technology and the rise of innovative terrorism," *Foundation for Political, Economic and Social Research (SETA)* (2017), 17.

<sup>21</sup> Friese, Jones and Smallwood, "Emerging Unmanned Threats: The use of commercially available UAVs by armed non-state actors," 31.

<sup>22</sup> Jackson, "Technology Acquisition by Terrorist Groups: Threat Assessment Informed by Lessons from Private Sector Technology Adoption," 22.

<sup>23</sup> *ibid.*, 9.

<sup>24</sup> Dutch Safety Board, *Crash of Malaysia Airlines Flight MH17 – Hrabove, Ukraine 17 July 2014* (Netherlands: The Hague 2015), 9.

<sup>25</sup> Rassler, *Remotely Piloted Innovation: Terrorism, Drones and Supportive Technology*, 1.

<sup>26</sup> Friese, Jones and Smallwood, "Emerging Unmanned Threats: The use of commercially available UAVs by armed non-state actors," 32.

<sup>27</sup> Balkan, "Daesh's Drone Strategy – Technology and the rise of innovative terrorism," 18.

<sup>28</sup> Friese, Jones and Smallwood, "Emerging Unmanned Threats: The use of commercially available UAVs by armed non-state actors," 10.

<sup>29</sup> *ibid.*, 10.

<sup>30</sup> Mark Pomerleau, "Counter-drone is the new counter-IED," *C4ISRNet*, March 21, 2017 <https://www.c4isrnet.com/unmanned/uas/2017/03/21/counter-drone-is-the-new-counter-ied/>.

<sup>31</sup> Jackson, "Technology Acquisition by Terrorist Groups: Threat Assessment Informed by Lessons from Private Sector Technology Adoption," 6.

<sup>32</sup> Rupert Smith, *The Utility of Force: The art of war in the modern world* (London: Penguin Books Ltd, 2005), 267.

<sup>33</sup> Jackson, "Technology Acquisition by Terrorist Groups: Threat Assessment Informed by Lessons from Private Sector Technology Adoption," 35.

<sup>34</sup> *ibid.*, 15.

<sup>35</sup> Balkan, "Daesh's Drone Strategy – Technology and the rise of innovative terrorism," 50.

<sup>36</sup> Conflict Armament Research, *Weapons of the Islamic State* (London, Conflict Armament Research Ltd, 2017), 8.

<sup>37</sup> *ibid.*, 110.

<sup>38</sup> Charles Clover and Emily Feng, "ISIS use of hobby drones as weapons test Chinese makers," *Financial Times*, December 11, 2017. <https://www.ft.com/content/82a29f96-c9e7-11e7-ab18-7a9fb7d6163e>.

<sup>39</sup> Balkan, "Daesh's Drone Strategy – Technology and the rise of innovative terrorism," 43.

<sup>40</sup> Gettinger, "Drones Operating in Syria and Iraq," 1.



<sup>41</sup> Balkan, "Daesh's Drone Strategy – Technology and the rise of innovative terrorism," 35.

<sup>42</sup> Waters, "Death From Above: The Drone Bombs of the Caliphate."

<sup>43</sup> Milton Hoenig, "Hezbollah and the Use of Drones as a Weapon of Terrorism," *Federation of American Scientists Public Interest Report* Spring 2014 Vol. 67 No. 2 (Spring 2014), 1.

<sup>44</sup> Waters, "Death From Above: The Drone Bombs of the Caliphate."

<sup>45</sup> Fars News Agency, "Hezbollah Drones Target Al-Nusra Front's Positions at Syrian Border," *Fars News Agency*, September 21, 2014. <http://en.farsnews.com/newstext.aspx?nn=13930630001247>.

<sup>46</sup> Waters, "Death From Above: The Drone Bombs of the Caliphate." – Evidence subsequently removed from YouTube for violation of the terms of service.

<sup>47</sup> *ibid.*, <https://www.bellingcat.com/news/mena/2017/02/10/death-drone-bombs-caliphate/>.

<sup>48</sup> *ibid.*, <https://www.bellingcat.com/news/mena/2017/02/10/death-drone-bombs-caliphate/>.

<sup>49</sup> *ibid.*, <https://www.bellingcat.com/news/mena/2017/02/10/death-drone-bombs-caliphate/>.

<sup>50</sup> Balkan, "Daesh's Drone Strategy – Technology and the rise of innovative terrorism," 36

<sup>51</sup> *ibid.*, 35.

<sup>52</sup> HMG, *Joint Doctrine Publication 0-30.2 – Unmanned Aircraft Systems* (HMSO: MOD Shrivenham, 2017), 33.

<sup>53</sup> Jed Judson, "Drone Warfare in Mosul Shapes US Army training to defeat airborne threats," *Defense News*, March 14, 2017. <https://www.defensenews.com/digital-show-dailies/global-force-symposium/2017/03/14/drone-warfare-in-mosul-shapes-us-army-training-to-defeat-airborne-threats/>.

<sup>54</sup> Alexandra Sander, *Game of Drones – Proliferated Drones*, (Washington DC: Center for a New American Security, 2016), 10 <http://drones.cnas.org/reports/game-of-drones/>.

<sup>55</sup> Balkan, "Daesh's Drone Strategy – Technology and the rise of innovative terrorism," 10.

<sup>56</sup> *ibid.*, 10.

<sup>57</sup> *ibid.*, 10.

<sup>58</sup> Frieze, Jones and Smallwood, "Emerging Unmanned Threats: The use of commercially available UAVs by armed non-state actors," 45.

<sup>59</sup> Balkan, "Daesh's Drone Strategy – Technology and the rise of innovative terrorism," 13.

<sup>60</sup> Operation Conquest was the ISF led mission to liberate the city of Mosul from ISIS control.

<sup>61</sup> Balkan, "Daesh's Drone Strategy – Technology and the rise of innovative terrorism," 25.

<sup>62</sup> *ibid.*, 30.

<sup>63</sup> *ibid.*, 31.

<sup>64</sup> *ibid.*, 33.

<sup>65</sup> Frieze, Jones and Smallwood, "Emerging Unmanned Threats: The use of commercially available UAVs by armed non-state actors," 47.

<sup>66</sup> Robert Bunker, *Terrorist and Insurgent Unmanned Aerial Vehicles: Use, Potentials and Military Implications*, (Pennsylvania: US Army War College Press, 2015), 20.

<sup>67</sup> *Amazon Prime Delivery* is a new technology being developed by Amazon for rapid,

autonomous delivery of products to customers <https://www.amazon.com/Amazon-Prime-Air/b?ie=UTF8&node=8037720011> Accessed 27 June 2018.

<sup>68</sup> Friese, Jones and Smallwood, "Emerging Unmanned Threats: The use of commercially available UAVs by armed non-state actors," 47.

<sup>69</sup> For the purpose of this analysis, it is argued Douhet's 'Command of the Air' is interchangeable with the more common term today of 'Control of the Air'.

<sup>70</sup> Giulio Douhet, *The Command of the Air*, trans. Richard Kohn and Joseph Harahan (New York: Coward-McCann, 1983), 24.

<sup>71</sup> Exact figures for the altitudes COTS can operate at vary with payload, power systems and the technology as it is developed. For the purposes of this analysis, 'lower' airspace is considered below 3000', whereas 'upper' airspace is seen as 10,000' and above.

<sup>72</sup> Chovil, "Air Superiority Under 2000 Feet: Lessons from Waging Drone Warfare against ISIL."

<sup>73</sup> Frew, "Drone Wars: The Next Generation – An overview of new armed drone operators," 24.

<sup>74</sup> Fox News, "Video shows fighter jets launch swarm of tiny drones," *Fox News*, January 10, 2017. <http://www.foxnews.com/tech/2017/01/10/video-shows-fighter-jets-launch-swarm-tiny-drones.html>.

<sup>75</sup> Friese, Jones and Smallwood, "Emerging Unmanned Threats: The use of commercially available UAVs by armed non-state actors," 35.

<sup>76</sup> Fox News, "Video shows fighter jets launch swarm of tiny drones."

<sup>77</sup> Drone DJ, "2018 Winter Olympics and Intel's record drone show," *Drone DJ*, February 9, 2018.

<sup>78</sup> Kelly Sayler, *A World of Proliferated Drones: A Technology Primer*, (Washington DC, Centre for New American Security, 2015), 29.

<sup>79</sup> Birmingham Policy Commission, "The Security Impact of Drones: Challenges and Opportunities for the UK," *Birmingham Policy Commission* (Birmingham: University of Birmingham 2014), 78.

<sup>80</sup> Blount and Sammut, "A Gift to Our People': The Use of Drone Technology by Islamist Insurgents," 2.

<sup>81</sup> Sander, "Game of Drones – Proliferated Drones," 2.

<sup>82</sup> Friese, Jones and Smallwood, "Emerging Unmanned Threats: The use of commercially available UAVs by armed non-state actors," 55.

<sup>83</sup> Jonathan Gillis, "In over their heads: US ground forces are dangerously unprepared for enemy drones," *War on the Rocks*, May 30, 2017. <https://warontherocks.com/2017/05/in-over-their-heads-u-s-ground-forces-are-dangerously-unprepared-for-enemy-drones/>.

<sup>84</sup> Operation Inherent Resolve is the US military name for operations against ISIS in both Iraq and Syria.

<sup>85</sup> Balkan, "Daesh's Drone Strategy – Technology and the rise of innovative terrorism," 11.

<sup>86</sup> Sayler, *A World of Proliferated Drones: A Technology Primer*, 12.

<sup>87</sup> Chovil, "Air Superiority Under 2000 Feet: Lessons from Waging Drone Warfare against ISIL."

<sup>88</sup> Bunker, *Terrorist and Insurgent Unmanned Aerial Vehicles: Use, Potentials and Military Implications*, 21.

<sup>89</sup> Faine Greenwood and Ossama Zaqqout, "Drones Don't Wear Uniforms. They Should," *Foreign Policy*, May 22, 2018.

<sup>90</sup> *ibid.*, <https://foreignpolicy.com/2018/05/22/drones-dont-wear-uniforms-they-should/>.

<sup>91</sup> Frew, "Drone Wars: The Next Generation – An overview of new armed drone operators," 6.

<sup>92</sup> Ressler, *Remotely Piloted Innovation: Terrorism, Drones and Supportive Technology*, 9.

<sup>93</sup> Sander, "Game of Drones – Proliferated Drones," 17.

## Article

# The RAF and its Approach to Science in The Interwar Period

By Mark Russell

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**Biography:** Mark Russell graduated with a 2:1 in History in 1985 and has worked in professional services ever since. He returned to academia in 2015 and graduated with an MA in Air Power: History, Theory and Evolution from the University of Birmingham in December 2017. His dissertation looked at whether the RAF was a learning organisation in the period 1925 – 1935, with special reference to how the Air Exercises helped the RAF develop and test tactics and technology. His current research interest is the RAF in the interwar years and how the organisation managed technological change.

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**Abstract:** This article considers the scientific resources available to the RAF in the interwar period, and how it used those resources to address one of its most pressing problems, namely the need to improve early warning of attacks against the UK. Ways of addressing the problem of early warning and its ultimate solution through the development of radar are used as a case study to look at whether this technology could have been developed earlier by the RAF.

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## Introduction

Early warning was not a new concern; during World War One the Chief of the Imperial General Staff (CIGS), General Sir William Robertson, noted 'the distance in time from the coast to important places like London is less than the time required by most of the machines we have got to ascend to the necessary height.'<sup>1</sup> The technology the RAF relied on before radar was sound mirrors (or acoustical mirrors as they were often referred to). The development of these was begun by the War Office during World War One, and their development continued throughout the 1920s and into the 1930s. The sound mirrors detection ranges never exceeded 25 miles, yet despite this, the RAF did not appear to have commissioned studies to actively look for technologies that could detect incoming aircraft at extended ranges. The development of radar to resolve this problem was not the result of a long-term approach by the Air Ministry to use science to solve operational issues; indeed, in 1948 Air Chief Marshal Dowding described the 'romantic discovery and development of Radio Location.'<sup>2</sup>

Before looking at how the RAF tried to address the early warning problem, it is useful to understand radar's history. In the mid-1930s, radar was not a new concept, either in terms of the scientific thinking behind it, or its practical demonstration; in 1904 a German engineer, Christian Hülsmeyer, demonstrated a technology that can be recognised as radar.<sup>3</sup> Hülsmeyer patented his 'Telemobiloscope' in Germany on 30th April 1904, with UK patents following in June and November 1904. His demonstrations to shipping lines were reported globally, including on 19th May 1904 by the New York Times; as a result, the concept was in the public domain. In 1922, Guglielmo Marconi, an Italian engineer and long-distance radio transmission specialist, had proposed a similar system to Hülsmeyer's but this again did not spur practical development.<sup>4</sup> Various papers published in the interwar period also suggested aircraft could be detected by radio waves.<sup>5,6</sup> There is no evidence however that the Air Ministry or any of the committees that advised it on scientific or technological matters knew of these developments, or considered them to be useful.

Technologies that can be recognised as radar were also developed elsewhere in the British military establishment. In 1928, LS Alder of the Royal Navy's HM Signals School 'had proposed to Admiralty [sic] a scheme for the detection and location of objects by radio.'<sup>7</sup> The entry in the Royal Engineers' Invention Book by Butement and Pollard on 26th January 1931 for a Coastal Defence Apparatus' can also be seen as proposing a form of radar.<sup>8</sup> The RAF appeared unaware of these developments, likely due to the lack of an inter-service scientific forum at this time.

This failure to recognise the potential of inventions was not restricted to radar; for example, Guy Hartcup, a military historian, notes that the proposal of gear synchronisation in order to allow a machine gun to fire through a propellor arc, had been made in both Britain and Germany before 1914, predating Anthony Fokker's invention and implementation of this.<sup>9</sup> The question then is what organisational structures and approaches the RAF had in place

during this period, and hence whether these might have proposed a radio-based solution to early warning earlier.

The first British body aimed at bringing science to bear on aeronautical problems, set up in 1909 under the auspices of the War Office, was the Advisory Committee on Aeronautics. Its role was to look at 'problems arising in connection with ... aerial construction and navigation.'<sup>10</sup> It thus had a very practical focus, rather than the broader scope to consider what science could offer to solve wider problems. The Secretary of State for War, John Haldane, did see a role for theoretical science, saying it should seek solutions 'by the application of both theoretical and experimental methods of research.'<sup>11</sup> However, the committee was reactive, responding to requests from the Services, rather than being proactive and volunteering ideas of how science could help solve problems facing them. Its effectiveness thus depended on the questions it was asked, and whether these were the key ones. This practical, reactive approach was to be the hallmark of most Governmental scientific bodies that followed it until the mid-1930s.

In 1920 the Advisory Committee on Aeronautics evolved to become the Aeronautical Research Committee (ARC), which, instead of reporting to the Prime Minister as Chairman of the Committee of Imperial Defence, reported to the Secretary of State for Air and the newly created RAF. It advised the Secretary of State for Air on 'higher matters of research', but it was focused on aeronautical matters, and so again did not consider wider air defence issues.<sup>12</sup> The committee continued to be reactive, and until 1935, was made up largely of members of the aircraft industry, therefore it could, perhaps, only have been expected to focus on research that would improve the aircraft which industry sought to build and sell. This was an essentially practical organisation, not one that was looking at basic science for the next generation of technology; the focus was more on the incremental improvement of existing technologies. So, while the ARC was a body created to bring science to bear on answering questions that the RAF might ask it to look at, it had no broader remit.

The RAF could call on other bodies for scientific support. These included the Aerodynamics Department of the National Physical Laboratory (NPL), which built its first wind tunnel in 1902, and its first supersonic wind tunnel in 1922.<sup>13</sup> The Royal Aircraft Establishment (RAE) at Farnborough also carried out aviation research across a range of areas associated specifically with the problems of flight and aircraft. Both bodies, especially RAE, were focused on research into the specific problems of flight. The Department for Scientific and Industrial Research (DSIR), established in 1916 as an independent ministry, became the responsible body to 'organize all the scientific work which is of common interest to the fighting services.'<sup>14</sup> This would seem to have made it an ideal body to have organised more wide-ranging research such as early warning, because clearly all the Services needed to be able to locate enemy aircraft. However, DSIR did not request or drive research in this area, perhaps because the Services had different needs around early warning; the RAF needed long range early warning, in contrast to the point defence of the Royal Navy and Army. The DSIR executed work in the

early 1920s to debunk stories from Germany about 'death rays' that could detonate explosives, but this did not lead to the further consideration and investigation of whether radio waves could detect aircraft.<sup>15</sup>

These were all external bodies that the RAF could call on, but in 1924 it also appointed a Director of Scientific Research (DSR) to be responsible for scientific research. This is the point at which the RAF might have been expected to begin to seek scientific advice to find solutions to the early warning problem. In 1940, Charles Grey reported 'the Research Department hunted for things, and the Department of Technical Development developed them into a state of being technically useful.'<sup>16</sup>

The first Director of Scientific Research, Harry Wimperis, was described by war correspondent, Ronald Clark, as 'an able engineer.'<sup>17</sup> Many years later Sir Henry Tizard was sceptical of the value of the post of DSR (which he had declined), saying 'He [DSR] had no responsibility, for instance, for radio research.'<sup>18</sup> Physicist and radar pioneer, Albert Rowe also comments on this, saying 'It is odd that ... armament, airships and radio were not his [DSR's] concern.'<sup>19</sup> This may explain why Wimperis as DSR was not looking at radio-based ways to address the early warning problem – it was not his area of responsibility, or area of technical expertise, hence turning to physicist Robert Watson-Watt in early 1935 for the definitive answer on whether a 'death ray', rumoured to be under development in Germany, was possible.

A key part of DSR's role was coordinating the various bodies that were undertaking research for the RAF, and providing 'the necessary liaison between those who carried out fundamental research on the problems of flight, those whose task it was to translate theoretical results into planes that flew, and those who physically piloted the planes.'<sup>20</sup> As this description shows, the role was firmly rooted in the challenges of flight; there was no idea that the role would look more widely at the world of science to see what it could provide as possible solutions to broader problems, such as early warning. So, neither DSR nor the ARC were expected to engage in basic research that had no clearly defined purpose, hence they would be unlikely to think broadly about how wider scientific developments might be of use.

This is not to suggest that the RAF failed to engage with science during this period; there was a range of activity, and one only has to look at some of the records set by the RAF and the advances behind these to recognise that research was being undertaken. However, this research might be termed 'tactical' – seeking improvements to aircraft and armaments, rather than looking to science to offer ideas on how more operational problems might be addressed. In adopting this tactical approach, the RAF was perhaps ignoring its early past, specifically the various studies executed by 'Viscount Tiverton', Major Hardinge Goulburn Giffard, who produced the first comprehensive plan for strategic bombing, whilst serving in the Royal Naval Air Service during World War One. While many of these studies focused on specific tactical problems, such as accurate bombing, they showed the way in terms of how science might be brought to bear on operational problems. The scientific approach had also been developed by

various others, including Tizard and Frederick Lindemann, in their work at Martlesham Heath and Farnborough respectively; again though, this work was essentially tactical, focused on improving aircraft and solving specific problems of flight.

This incremental focus is also borne out by review of DSR's quarterly reports on research. These show a strong focus on practical research, each being introduced by a statement that 'These investigations aim at the elucidation of (a) new methods of solving aeronautical problems, and (b) the discovery of the reasons why existing methods of solution sometimes fail; the application of such solutions, from whatever source they may come, to the needs of the service and civilian aviation, is a matter for technical development, and is not therefore dealt with in this report.'<sup>21</sup> The summaries show what the DSR considered in his overview of research in progress. The structure was based on the research establishments and the research is very much focused on practical application of technology. The Air Ministry did fund the Air Ministry Laboratory at Imperial College in South Kensington, but this too demonstrated the strong focus on practical research notable in the DSR's reports.

These quarterly reports do not include any overview of relevant scientific advances or literature to consider their potential usefulness in an RAF context. This lack of a watching brief on wider research was a significant omission in their approach to bringing the best of science to address the RAF's problems. Neither is there mention of the work being carried out at the War Office's Air Defence Experimental Establishment (ADEE) on sound mirrors, an unusual omission given how important this work was to the whole air defence concept. Including a review of progress in the sound mirrors research might have triggered challenges to its progress, and likely utility, earlier than these were actually raised.

Until the creation of the Committee for the Scientific Study of Air Defence (CSSAD) in 1934, the RAF was not organisationally structured to bring science to bear on its more general problems (although Hartcup notes that both the Royal Navy and the Army had, since 1900, set up various civilian committees to provide advice on how science could improve various technologies).<sup>22</sup> Research was 'controlled by competent and conscientious RAF officers who concentrated upon improving the weapons familiar to them' according to AP Rowe, Wimperis' deputy.<sup>23</sup> This was their focus, and no doubt there were more than enough of these problems to occupy them, without any fanciful notions of long range aircraft detection being added to the to-do list. The greater failing, if one is to put it that way, is that there was no effective mechanism in the Air Ministry to frame broad questions for scientific advisers, in such a way, as to encourage them to look widely across science and published research to find solutions to these problems.

This omission continued in the manner that the RAF addressed the problem of early warning. The War Office had experimented with sound mirrors, building on its research into using sound to locate enemy artillery batteries. Two mirrors had been built, one at Fan Holes near South Foreland and one at Joss Gap near North Foreland. These were parabolic reflectors, carved into



chalk cliffs, with subsequent mirrors either carved into cliff faces and given a smooth concrete face or built from reinforced concrete. These symmetrically planed mirrors were a success; 'the Joss Gap mirror ... did very good work. It was instrumental in giving warning ... before the sounds could be picked up by the ear on the shore.'<sup>24</sup> DSIR noted in July 1919 that aircraft could be heard at seven or eight miles, with the sound being 'very loud' even when 'it is quite inaudible to the unaided ear.'<sup>25</sup> So this was a technology that had been tested under wartime conditions and was assessed as effective.

Research continued after the end of the war in the Acoustical Research Section (ARS), funded by the War Office. In 1929 the ARS was absorbed into the War Office's Air Defence Experimental Establishment (ADEE). Created in 1925, the ADEE was staffed with between 15 and 20 people, making it 'one of the largest military scientific programmes.'<sup>26</sup> The RAF provided test aircraft when requested to support experiments but does not appear to have been involved in this work in the development of this programme in the early 1920s to improve the early warning available through sound mirrors. Despite this in '*Years of Command*', Marshal of the Royal Air Force, Lord Sholto Douglas, stated that '*A great deal of thought was being given even then [i.e. the 1920s] to matters of home defence.*'<sup>27</sup> The French 'scare' of 1923 that prompted the agreement to expand the Home Defence force to 52 squadrons does not seem to have triggered an increased interest and involvement in the Army's work on sound mirrors. Ferris believes that the RAF had a 'powerful' relationship with scientists in the interwar period, with the development of sound mirrors 'showing a willingness to apply science to air defence.'<sup>28</sup> However, it was not the RAF using science to address the question of early warning; it was the War Office; in the 1920s the RAF itself did not appear to have considered whether another, better, approach might be possible.

A broader review of the approach to anti-aircraft defence came from the Anti-aircraft Research Sub-committee, that the Committee for Imperial Defence (CID) had set up under the ARC in May 1925. Its membership included all three Services, and its meeting records show the RAF took this issue seriously. It focused on the tactical question of identifying and then destroying enemy aircraft, and, it considered a range of potential technologies, including acoustical methods, the possibility of tracking aircraft based on the electromagnetic emissions from their engines, and infra-red detection.<sup>29</sup>

The ARC's 1926 report concluded that sound mirrors were the only practical early warning technology, despite their known technical limitations, which had been explored throughout the 1920s. One problem was that the system had to be tuned to specific engines, which presupposed knowledge of the acoustic signature of those engines; 'the exhaust sound of the Hinaidi bombers used in the night raids during the Exercises is quite outside the range of the existing microphones.'<sup>30</sup> The system could also be compromised by early stealth technology; 'The Hinaidi is notably quiet, and has been known to fly over Anti-Artillery troops at 15,000 ft without being detected. Its acoustic output ... is only one-fifth of that sent out from a Vickers Virginia.'<sup>31</sup> This was not just an issue for early warning; the War Office was also depending

on sound locators to allow anti-aircraft batteries to target bombers at night, and silencing engines was investigated by the RAF to help make its own bombers harder targets for enemy anti-aircraft guns. Trials with unsilenced and silenced Heyford aircraft in 1935 showed that this technology could reduce warning times by on average five minutes, from circa 11 minutes to circa six minutes.<sup>32</sup> Weather could impact on their performance, with 'wide fluctuations in range caused by weather conditions' being noted.<sup>33</sup> Other sound could also cause problems, with 'jamming by the sound of the propellers of passing ships' being noted on occasions.<sup>34</sup>

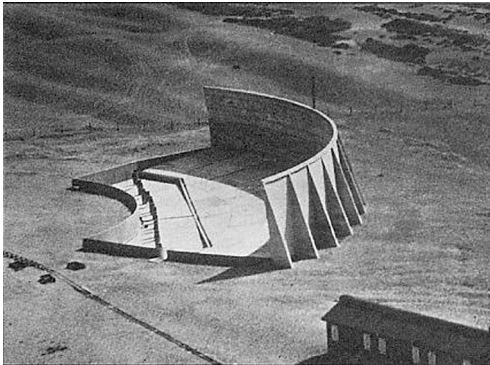
These issues were constantly re-examined to see if solutions could be found; for example, a Signals Experimental Establishment (SEE) – the Acoustical Research Section's parent before the Air Defence Experimental Establishment was set up – report on 27th February 1922 shows that research was being done into the problems caused by rain, fog and mist, and wind.<sup>35</sup> ADEE's summary of 1933 trials makes some of the problems with this technology clear.<sup>36</sup> The War Office's own manuals also noted that the effectiveness of sound location depended on the aspect of the aircraft; 'if the machine is end-on (receding or approaching) the sound of the airscrew [a key component of the sound to be detected] cannot be heard.'<sup>37</sup> Incremental improvements were made to the technology over time, with 'mean maximum of 22.1 miles, as compared with that obtained at the earlier trials [ADEE report 62, October 1931] of 16¾ miles' in the July 1933 trials.<sup>38</sup>

This work was aimed at addressing the limitations of sound mirrors. Radio-based detection from the ground, (what would become radar), was not considered in either in the ARC's 1926 report or later; although the Memorandum ARC Paper No. 43 contains the tantalising phrase that 'It is therefore possible that a method of location [of aircraft] ... by secondary excitation in a strong field emitted by a ground transmitter...' – but this was taken no further.<sup>39</sup> Between 1925-26 the ARC Sub-committee also considered whether the detection range could be increased by stationing observers offshore but discounted this proposal as ineffective. In November 1934 the ADEE reported that listening ranges would not significantly improve.<sup>40</sup> Furthermore, DSR concluded that 'performance is not sufficiently good to make trawler-listening of practical utility', and the Royal Navy had concluded that problems of station keeping and vulnerability to attack would make this solution impractical.<sup>41</sup>

War Office reports on progress with the mirrors were copied to the Air Ministry so that the Air Ministry was aware of the work being done, and its potential limitations, from the outset. Despite these issues, the RAF continued to look to sound mirrors to provide the early warning it needed throughout the 1920s and into the 1930s, alternate programmes championed by the RAF failed to emerge. Why this might be the case is discussed below; DSR did not initiate any research programmes in this area though until the creation of the Committee for Scientific Survey in Air Defence (CSSAD) in 1934.

There was an early appreciation of the potential limitations of the technology, and ranges were not expected to be huge; 'the 20ft and 30ft mirrors are designed to give warning and sound

bearings at ranges up to 10 miles, and the 200ft mirror to give warning and bearings at ranges up to 25 miles.<sup>42</sup> Construction of the larger sound mirror at Denge, near Dungeness, began in 1928 and was completed by July 1930. This was the ultimate expression of sound mirror technology, 200ft long and 25ft feet high, the longer wavelengths it sought to detect did not need the full parabolic mirror. It sat alongside the 20ft and 30ft mirrors that provided more accurate data on incoming raids once the larger mirror had detected the raid. Such a large mirror was needed 'because the most penetrating sounds for long distance transmission' could only be detected by the larger mirror, using microphones rather than the human ear.<sup>43</sup>



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<http://www.andrewgrantham.co.uk/soundmirrors/locations/denge/>

Despite all the known issues with the technology, given aircraft speeds and altitudes in the 1920s, a warning of up to 25 miles was helpful. Air Vice-Marshal J Salmond, AOC-in-C Air Defence of Great Britain (ADGB) stated in 1925 that if aircraft could be detected at 15 instead of 10 miles this 'would be of considerable value to the air defence of the country.'<sup>44</sup> The RAF's requirements for early warning were defined in November 1925 as being detecting aircraft at a range of 25 miles from the coast, with height, speed, course and number of aircraft being detected at 10 miles range – so the sound mirrors met the RAF's requirements at the time.<sup>45</sup>

In 1926 the Air Ministry began to contribute to funding the early warning programme, stating in December that the programme was 'fundamental to the scheme of defence.'<sup>46</sup> Despite this, not all were convinced the RAF should contribute. In *'Echoes from the Sky'* Richard Scarth notes the Chief of the Air Staff (CAS), Air Chief Marshal Trenchard, expressing alarm on 23 March 1928 that the RAF should be asked to fund work 'which relieves the other services of their legitimate responsibilities.'<sup>47</sup> This is likely to be more indicative of inter-Service budget battles, rather than CAS objecting to the technology per se.

By the early 1930s the RAF was considering testing the early warning technology in the annual Air Exercises. These Air Exercises were the main, albeit limited, opportunity to test all the components of the air defence system simultaneously, including new technology and tactics. To this end, the sound mirrors were included in the 1933 Air Exercises, and AOC-in-C ADGB, Air

Marshal G Salmond's Report on the 1933 Air Exercises said that 'the information was of definite value.'<sup>48</sup> The mirrors continued to be incorporated into the Air Exercises, being tested again in 1934 when 'little or no use of the early warning' was possible due to other aircraft movements, a problem that was never resolved.<sup>49</sup> They also appeared in the 1935 Exercises, a final flourish given the AOC's comment that their range 'is not great enough in the case of a really fast moving enemy'.<sup>50</sup> However, this was the best technology available, and the results of the trials in the 1933 Air Exercises had been encouraging enough for ADGB to propose in November 1933 'a scheme for the employment of a number of 200ft strip mirrors and 30ft bowl mirrors to provide a continuous warning screen from the south-east of England from the Wash to St. Albans Head'.<sup>51</sup> This proposal could not be fully funded so 'Air Marshal Salmond had therefore asked that the mirror system should be provided to cover the Thames Estuary'.<sup>52</sup> The aim was to have these mirrors built and operational in time for the 1935 Air Exercises.

However, the scheme stalled and it was not until 17 December 1934 the Air Council told AOC-in-C ADGB that the mirrors for the Thames Estuary part of the scheme had been approved.<sup>53</sup> The Thames Estuary scheme progressed through 1935, with significant resources being earmarked for it, demonstrating the seriousness attached to early warning by the RAF.<sup>54</sup> However, on 15 August 1935, the project was suspended by the incoming AOC-in-C, Air Marshal Steel, possibly because of the promise shown by the early Radio Direction Finding experiments. In January 1936, CSSAD's survey of air defence noted the scheme was 'in abeyance pending the results of RDF location'.<sup>55</sup> The idea of building mirrors in Singapore and Hong Kong was also raised in 1935, but it was concluded that the 3¾ minutes of additional warning they would give the RAF at Singapore meant 'acoustical mirrors would be of no value'.<sup>56</sup>

The withdrawal of RAF support for sound mirrors in late 1934-35 was understandable. By November 1934 the warning time provided by sound mirror technology was unable to meet the RAF's requirements, which had evolved and were being expressed as a requirement for a 16 minute warning, made up of five minutes to recognise the raid and launch fighters in response, and 11 minutes for them to then get to an interception height of 20,000'.<sup>57</sup> This translated into a requirement for a warning range of 70 miles, assuming bombers flying at 250 mph. This demonstrates sound mirror technology had been overtaken, by the increased speed of the attacking aircraft, in terms of their ability to provide adequate warning.

During the 1930s, the RAF realised the need to improve early warning as aircraft speeds and altitudes increased significantly, which resulted in the trials of broader solutions. The 1932 Air Exercises included the use of an 'aircraft observation patrol,' which had been utilised in the First World War.<sup>58</sup> These patrol aircraft tried to spot incoming raids and shadow them while providing information on the raid to ADGB, a variant of which was tried in the 1930 Exercises.<sup>59</sup> AOC Fighting Area's conclusion in 1932 was that 'There is as yet insufficient experience to judge whether reconnaissance aircraft are of any assistance for detecting raids'.<sup>60</sup> AOC-in-C ADGB, Air Marshal G Salmond was more positive, believing that 'development is justified'.<sup>61</sup>

The 1933 Exercises concluded that 'these patrols are of considerable value.'<sup>62</sup> In the 1934 Air Exercises AOC-in-C ADGB, Air Marshal Brooke-Popham, concluded that 'they hold out the prospect of giving valuable early warning.'<sup>63</sup> However, after the 1935 Air Exercises the next AOC-in-C ADGB, Air Marshal Steel had a different view, saying 'I feel that there are more efficient and less wasteful methods of achieving the same object [earlier warning of raids].'<sup>64</sup> He did not specify these; it is possible that he had an early awareness of the work that had already begun around RDF.

These attempts to improve early warning show those RAF leaders charged with defending the UK appreciated the importance of early warning to an air defence system. They continued to look at a range of approaches to address this problem, as befitted a Service that prided itself on its technical capabilities. While, with hindsight, sound mirrors can be seen to have been a dead end, their pursuit as a technology that could offer earlier detection of incoming aircraft and hence address a key problem of air defence was entirely rational at the time; in '*Tucker's Acoustical Mirrors*' David Zimmerman is overstating the case in describing sound mirrors as 'a case study of everything that can go wrong in a military scientific development programme'.<sup>65</sup> What is true is that by 1935, when the Air Ministry withdrew funding from the programme, increased aircraft speeds and altitudes meant that detection at ranges of 70 miles or more was needed and sound mirrors could never have achieved this.

However, as the shortcomings of sound mirrors became evident, the RAF's approach to science meant alternatives were not identified. There was no expectation that DSR or any other Air Ministry or government body such as DSIR would look to basic science to identify possible solutions to this pressing operational problem. Until the creation of CSSAD, the RAF did not create a research agenda or approach that called on science as a source of new ideas or technologies, to address fundamental problems, including early warning. In contrast, in the Royal Navy's case, the invention of ASDIC, a sonar system to detect submerged submarines, had shown how science could help solve fundamental problems. Zimmerman notes that 'the armed forces tended to see its scientists as being the producers of gadgets'.<sup>66</sup> This mindset meant many scientists saw military work as 'essentially second rate and dull,' which hardly encouraged them to work with the military.<sup>67</sup> There was also limited funding available, and an understandable inclination to spend it on work that might have practical, and more immediate, benefits. Thus, DSR's quarterly reports show the limited funding for university researchers being directed to specific aeronautical problems, rather than broader innovative enquiries.

Essentially, there was a lack of any science-based approach to solving broader problems in the RAF, even though scientists had done work that might have been developed to provide better early warning. This work was either overseas (e.g. Hülsmeyer), relatively theoretical (e.g. Marconi), done by the Royal Navy or Army, or outside the military realm (e.g. the Post Office papers noting the effects of passing aircraft on radio transmissions). One possible explanation why investigation into radar was not developed may be that those with the knowledge of

this concept rejected it because they believed the wood and fabric structure aircraft of the time would not provide a strong enough echo to make radar useful.<sup>68</sup> Wilkins notes that such an aircraft was used for tests in 1935 to see if it could be detected by RDF, and the 'range for detection was about halved'.<sup>69</sup> However, if the technology was consciously discounted for this reason, no trace exists in the records, while other ideas for detecting aircraft, such as radiation emitted by magnets, was considered even when it was known this was unlikely to work.<sup>70</sup>

Where the RAF and Air Ministry perhaps fell short was that they failed to identify the technology which would later develop into radar, as a viable, alternative solution to the early warning problem; Zimmerman saying 'little or no effort had been made to call on science to find a way out.'<sup>71</sup> This failure to identify radio as a promising solution is not solely their fault; the two CID Sub Committees on Anti-aircraft Defence had also failed to consider this approach, while considering a range of other technologies and rejecting them. Brown believes that information about the various experiments described above 'must have spread widely and informally' among researchers, but the Air Ministry and RAF lacked the contacts with such networks.<sup>72</sup> Watson-Watt talks of 'the wide open tool-box of ideas from which the weapon of radar might be forged' when surveying the scientific work done before his practical work leading to radar; the question is why this 'tool-box' did not lead to radar earlier.<sup>73</sup> This is echoed by AF Wilkins, who notes the effects described to him by Post Office engineers on aircraft disrupting VHF transmissions in 1930-31, but he, the Post Office, and the Radio Department at RAE 'failed to look further into the matter,' probably because sound mirrors were the approved solution.<sup>74</sup> In the Air Ministry files one can occasionally find mentions of interesting experiments overseas, but there was no systematic way to identify and assess those which may have been of interest.<sup>75</sup> The idea of a 'literature search' was recognised in the Air Ministry: in October 1923 a committee created to study defence against pilotless aircraft looked in patents to understand how such aircraft might be controlled.<sup>76</sup> However, there is no evidence that this approach was used to for solutions to the early warning problem.

The bigger question is why the RAF did not do more to directly fund or pursue 'blue sky' thinking into the challenge of early warning. In February 1935 radar was developed in the UK thanks to Watson-Watt and AF Wilkins, who investigated further the work initiated by Wimperis, whilst answering his question about the feasibility of 'death rays', to show that radio detection of aircraft was technically possible. The failure to identify radio-based technologies as a possible solution to the early warning problem thus lies with the way the RAF had defined the role of the DSR (which excluded radio matters) and the broader failure to link science with the RAF's most pressing problems.

CSSAD was the RAF's first attempt to look to science for solutions to its most pressing problems, and its terms of reference required it to 'consider how far recent advances in scientific and technical knowledge can be used to strengthen the present methods of defence against hostile aircraft.'<sup>77</sup> These terms of reference, drafted by Wimperis, were much more wide-ranging than those given to the previously described committees. Through these

terms CSSAD was invited to start from first principles and thus saw the first effective attempt by the RAF to bring civilian science to bear on its critical problems. However, even once RDF was under development, some believe the RAF failed to call on the 'best and brightest' to drive the concept forwards. Brown notes the failure of the Air Ministry's to identify and call upon the best civilian technology and people (citing EMI's television research team that included nine relevant PhDs) as the Chain Home system was built.<sup>78</sup> Given the speed with which the Chain Home stations were commissioned, it is hard to see this as having significantly slowed the project down.

Britain was not the only country that suddenly saw radar development take off in the mid-1930s. Many countries took radar research seriously from this time, including France, Italy and the Netherlands, as well as the 'usual suspects' of Britain and Germany.<sup>79</sup> Brown suggests that this may be partly because various scientific researches and advances in technology came together at this time to make radar a more practical technology. The question is whether this research could have been accelerated had the funds devoted to sound mirrors instead been focused on research into what became radar. There are understandable reasons why this did not happen, including, perhaps, the importance placed on air defence by the RAF; stopping development of an established technology (sound mirrors), that during the 1920s offered some benefits, to work on a non-existent technology that theoretically could be developed to a point where it would offer significantly greater benefits, would have been a brave step. It took the increasing aircraft speeds in the 1930s to make sound mirrors obviously obsolete; before that, they could still provide 'information ... of definite value.'<sup>80</sup>

It is likely that organisational inertia also came into play; a programme was in place, was funded, was proceeding; such things often acquire a life of their own. However, the programme was owned by the War Office, whose need for effective long-range early warning was not as great as the RAF's. This may be why the RAF so swiftly withdrew support from sound mirrors once RDF began to look feasible; having gained initial assurance that RDF was viable, and could be delivered quickly, they focused resources on RDF rather than sound mirrors.

Perhaps one explanation why the RAF did not pursue radar earlier is the background of the scientific advisers; had DSR not been a mechanical engineer and had he spent less time on combustion investigation and more on radio investigation, radar might have emerged earlier. Furthermore, had DSR's remit not specifically excluded radio research, Watson-Watt's 'tool-box' might have been opened and used earlier.

AP Rowe acknowledges that the theory behind radar was well enough known, but states that the 'catalytic agent was a request from a defence department concerned with the destruction of hostile aircraft.'<sup>81</sup> Bowen, one of the other early British pioneers, praised Swords' book, saying it 'finally gives the lie to Watson-Watt's claim to have invented everything.'<sup>82</sup> But the earlier development of radar must remain an interesting 'what if' since it did not



happen, and given Britain as a nation had not really properly worked out how to use science to solve applied problems faced by government (DSIR being a new creation in the 1920s), to expect such a step forward is probably unreasonable.

## Notes

<sup>1</sup> Robertson to Haig, 15 June 1917, Robertson Papers, 1/23 Liddell Hart centre for Military Archives, cited in J Ferris, 'Airbandit': C3I and Strategic Air Defence, 1915-18, p. 41, in M Dockrill and D French, *Strategy and Intelligence: British Policy during the First World War*, (London, Hambledon Press, 1996).

<sup>2</sup> MRAF Sir H Dowding, *The Battle of Britain*, (London, The London Gazette, 11th September 1948), Para. 54.

<sup>3</sup> Pritchard, *The Radar War: Germany's Pioneering Achievement 1904-45*, (Wellingborough, Patrick Stephens Limited, 1989), p. 7.

<sup>4</sup> G Marconi, *Radio telegraphy*, (London, Proceedings of the Institute of Radio Engineers, Vol. 10, Issue 4, August 1922), pp. 215-238.

<sup>5</sup> L Brown, *A Radar History of World War II: Technical and Military Imperatives*, (Bristol, Institute of Physics Publishing, 1999), p. 42.

<sup>6</sup> R Burns (ed), *Radar Development to 1945*, (London, Peter Peregrinus on behalf of the Institute of Electrical Engineers, 1988), Preface.

<sup>7</sup> Burns, *Radar Development*, para 4, p. 55.

<sup>8</sup> Brig AP Sayer, *Army Radar*, (London, The War Office, 1950), p. 301.

<sup>9</sup> G Hartcup, *The War of Invention: Scientific Developments, 1914-18*, (London, Brasseys, 1988), p. 146.

<sup>10</sup> Prime Minister HH Asquith to the House of Commons, 5 May, 1909.

<sup>11</sup> AM Gollin, *The Impact of Air Power on the British People and their Government, 1909-1914*, (London, The MacMillan Press Ltd, 1989) p. 45.

<sup>12</sup> Air Ministry, AP3368, *The Origins and Development of Operational research in the Royal Air Force*, (London, Her Majesty's Stationery Office, 1963), p. 2.

<sup>13</sup> <http://www.npl.co.uk/about/history/research/wind-tunnels/brief-guide-to-the-npl-aerodynamics-division> accessed on 7 October 2018.

<sup>14</sup> RW Clark, *Tizard*, (London, Methuen & Co., 1963), p. 57.

<sup>15</sup> Clark, *Tizard*, p. 62.

<sup>16</sup> CG Grey, *A History of the Air Ministry*, (London, George Allen & Unwin, 1940), p. 126.

<sup>17</sup> Clark, *Tizard*, p. 69.

<sup>18</sup> Clark, *Tizard*, p. 71.

<sup>19</sup> AP Rowe, *One Story of Radar*, (Cambridge, Cambridge University Press, 1948), p. 1.

<sup>20</sup> Clark, *Tizard*, p. 66.

<sup>21</sup> AIR 10/1205, Directorate of Scientific Research. Progress Report for Quarter ending 31st December 1925, Preface.

<sup>22</sup> Hartcup, *War of Invention*, pp. 7, 24 and 15.

<sup>23</sup> AP Rowe, *One Man's Story of Radar*, p. 1.

<sup>24</sup> DSIR 36/4427 – Acoustic Research – Detection and Location of Aircraft – Sound Mirror



System, Signals Experimental Establishment, Sound Mirrors for Anti-Aircraft Defence, p. 3.

<sup>25</sup> DSIR 36/4426, Acoustic Research – Detection and Location of Aircraft Disc System – Report 19, 1 July 1919, para 2. P 4.

<sup>26</sup> D Zimmerman, *Britain's Shield: Radar and the defeat of the Luftwaffe*, (Stroud, Amberley, 2010), p. 31.

<sup>27</sup> MRAF Sholto Douglas, *Years of Command*, (London, Collins, 1966), p. 27.

<sup>28</sup> J Ferris, Achieving Air Ascendancy: Challenge and Response in British Strategic Air Defence, 1915-40, p. 39, in S Cox and P Gray, *Air Power History: Turning Points from Kitty Hawk to Kosovo*, (London, Frank Cass, 2002).

<sup>29</sup> CAB 16/67, Anti-aircraft Research Sub-committee - Proceedings.

<sup>30</sup> AVIA 17/22 The use of sound mirrors by RAF Personnel during the ADGB Exercises, 1933 para 43v.

<sup>31</sup> AVIA 17/22 The use of sound mirrors by RAF Personnel during the ADGB Exercises, 1933 para 43vi.

<sup>32</sup> AVIA 17/41 Summary of tests of the 200 ft. acoustical mirror at Denge with silenced Heyford K.4021, para 8.

<sup>33</sup> AVIA 17/22 The use of sound mirrors by RAF Personnel during the ADGB Exercises, 1933, para 43viii.

<sup>34</sup> AVIA 17/24 Report on Acoustical Range Tests of the 200 foot mirror at Denge June 1933, ADEE Acoustical report No. 85, November 1933, p. 1 Summary.

<sup>35</sup> DSIR 36/4503, SEE report No. 170, 28th February 1922, p. 10.

<sup>36</sup> AIR 20 155 Use of sound mirrors by RAF personnel during the ADGB Exercises 1933, p. 16 – 17.

<sup>37</sup> WO 33/1360 The Theory of Anti-Aircraft Sound Location and Detection, p. 53.

<sup>38</sup> AVIA 17/24 Report on Acoustical Range Tests of the 200 foot mirror at Denge June 1933, ADEE Acoustical report No. 85, November 1933, p. 1 Summary.

<sup>39</sup> CAB 16/67, Anti-aircraft Research Sub-committee - Memorandum ARC Paper No. 43.

<sup>40</sup> AIR 20/145 ADEE 'Listening at Sea', 26th November 1934, Conclusion, p. 4.

<sup>41</sup> AIR 20/145 S.33402/DSR, Report on Listening from Trawlers, 17th December 1934, p. 2.

<sup>42</sup> AVIA 17/22 – The use of sound mirrors by RAF Personnel during the ADGB Exercises, 1933, para. 5.

<sup>43</sup> Scarth, *Echoes*, p. 98.

<sup>44</sup> CAB 16/67 Minutes of Third Meeting of the ARC, 8 July 1925.

<sup>45</sup> CAB 16/67 ARC paper 23, 25 November 1925.

<sup>46</sup> CAB 16/67 JA Webster, Air Ministry to ARC, 21 December 1926.

<sup>47</sup> Scarth, *Echoes*, p. 83.

<sup>48</sup> AIR 20/185 Report on Air Exercises 1933, 30th October 1933, para 11.

<sup>49</sup> AIR 20/186 Report on the 1934 Air Exercises, 23rd October 1934, para 79.

<sup>50</sup> AIR 20/184 Report on the 1935 Air Exercises, 25th November 1935, para 136.

<sup>51</sup> AIR 16/319 Acoustical Mirror Warning System: Thames Estuary Scheme, Encl 1B, Draft minutes of a conference held in Room 607, Air Ministry on 19th December 1933, para. 1.

<sup>52</sup> AIR 16/319 Acoustical Mirror Warning System: Thames Estuary Scheme, Encl 1B, Draft

minutes of a conference held in Room 607, Air Ministry on 19th December 1933, para. 2.

<sup>53</sup> Scarth, *Echoes*, p. 315.

<sup>54</sup> Scarth, *Echoes*, pp. 315 - 324.

<sup>55</sup> AIR 20/145, CSSAD, Appreciation of the Present Position, 6th January 1934, p. 4.

<sup>56</sup> AVIA 7/3103, Singapore and Hong King mirrors - Enc 3A – minutes of a meeting held at the War Office on 28 May 1935 to consider the advisability of providing an Acoustic Mirror Warning System at Singapore, p. 3.

<sup>57</sup> CAB 13/18 CID Home Defence Committee Sub-committee on the re-orientation of the Air Defence of Great Britain, ADGB Papers Nos. 1-50, Paper 14, Warning Period.

<sup>58</sup> Maj Gen E B Ashmore, *Air Defence*, (London, Longman, Green and Co., 1929), p. 42.

<sup>59</sup> Flt Lt W M Yool, *Air Exercises 1930*, JRUSI, Vol. 75, 1930, pp. 755 – 762.

<sup>60</sup> AIR 10/1523 Report on Air Exercises 1932, para 74iii.

<sup>61</sup> AIR 10/1523, Report on Air Exercises 1932, 30th September 1932, para 48vi.

<sup>62</sup> AIR 20/185 Report on Air Exercises 1933, 30th October 1933, para 20.

<sup>63</sup> AIR 20/186 Report on the 1934 Air Exercises, 23rd October 1934, para 103.

<sup>64</sup> AIR 20/184 Report on the 1935 Air Exercises, 25th November 1935, para 140.

<sup>65</sup> Zimmerman, *Tucker's Acoustical Mirrors*, p. 73.

<sup>66</sup> Zimmerman, *Britain's Shield*, p. 58.

<sup>67</sup> Zimmerman, *Britain's Shield*, p. 58.

<sup>68</sup> As a historian, I lack the scientific skills to know if this is true; however, I make the statement based on independent discussions with Richard May and Niall McConville, holders of MScs in Physics from Oxford and Cambridge respectively, who I am confident know what they are talking about in agreeing with this statement.

<sup>69</sup> Kinsey, *Orfordness*, p. 148.

<sup>70</sup> CAB 16/67, Anti-aircraft Research Sub-Committee - Minutes of first meeting on 5th July 1926

<sup>71</sup> Zimmerman, *Britain's Shield*, p. 72.

<sup>72</sup> L Brown, *A Radar History of World War II*, p. 42.

<sup>73</sup> Sir R Watson-Watt, *Three Steps to Victory*, (London, Odhams, 1957), p. 94.

<sup>74</sup> AF Wilkins, *The Early Days of Radar in Great Britain*, November 1977, GBR/0014/AWLK, Churchill College Archives Centre, p. 6.

<sup>75</sup> e.g. AIR 5/254, Abstract from German Press dated 21st December 1922, which discusses the transmission of conversations using infrared signalling – this is included in a file about RAE experiments on an infrared technology to help aircraft locate airfields, although the document notes it should be filed in the "Secret Signalling" file.

<sup>76</sup> AIR 5/487 Defence against Pilotless Aircraft, Minutes of First Conference, 24th October 1923, para. 2g.

<sup>77</sup> Clark, *Tizard*, p. 112.

<sup>78</sup> Brown, *A Radar History of World War II*, p. 58.

<sup>79</sup> See the many chapters in Burns, *Radar Development*, outlining these various developments.

<sup>80</sup> AIR 20/185 Report on Air Exercises 1933, 30th October 1933, para 11.

<sup>81</sup> AP Rowe, *From Scientific Idea to Practical Use*, (London, Minerva, Spring 1964), p. 305 – held in RACL 4/29 at the Churchill College Archives Centre.

<sup>82</sup> EG Bowne to JA Ratcliffe, May 21, 1984, held in RACL 4/3 at the Churchill College Archives Centre.

## Book Review

# Global Defense Procurement and the F-35 Joint Strike Fighter



By Bert Chapman

**Publisher:** Palgrave Mcmillan, 2019 (ISBN: 978-3-030-01367-7), 396 pages

Reviewed by Air Commodore (Retd) Al Byford

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**Biography:** Air Commodore Al Byford flew over 4,000 hours as a Tornado pilot in a 36-year RAF career, including deploying on 12 named operations. He is now the Defence and Political Adviser for MBDA Missile Systems.

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## Introduction

The F-35B Lightning will provide the core of the UK's combat air capability over the next two decades, complementing Typhoon with the high-end, fifth generation capabilities required to defeat the emerging threats based on Russian and Chinese technology which are now proliferating in areas of key national interest to the UK. The F-35 is also critical to UK prosperity, as it sustains up to 25,000 jobs in the aerospace sector whilst the UK's initial status as a 'Tier 1' partner means it benefits from a 15% share of F-35 production, anticipated to run to some 3,000 aircraft.

However, the F-35 enterprise has never been far away from controversy: it has been subject to repeated delays, technical problems and cost overruns, whilst from a UK perspective, changing military requirements and political vacillation have threatened to derail the project over a series of defence reviews; the debate about numbers and force-mix (in terms of which variant to procure) continues. Nevertheless, the UK declared initial operating capability in December 2018 and became only the third F-35 user (after the US and Israel) to employ the aircraft under combat conditions on Operation Shader in June this year. So as the force build-up continues, this is a useful point to review how the programme has evolved over time and where it may go in the future. In his new book, Bert Chapman, a professor at Purdue University, helps us to do just that. *Global Defense Procurement and the F-35 Joint Strike Fighter* charts the origin and

development of the F-35 as a genuinely multinational enterprise where military, industrial and political requirements intersect within a context of emerging international geopolitical and security trends.

The layout is logical and brings coherence to an otherwise complex topic. The author begins by situating the F-35 within a historical overview of jet fighter aircraft development, discussing different generations and their technical characteristics. Next, he assesses the threat context the F-35 is designed to operate in – providing much useful information on emerging Russian and Chinese capability in its own right – before examining, in subsequent chapters, the different experiences of the key national partners in turn.

Whilst RAF readers will clearly be most interested in the UK chapter, the relative international comparison is informative because a common pattern emerges. Rising cost, developmental challenges and delivery delays spark controversy and criticism, but the lack of competition and the technical difficulty of the requirement mean F-35 is the only really credible fifth-generation option, so national procurement programmes continue for a broadly similar mix of reasons: military necessity; political expediency; and industrial self-interest. In this sense the complexity of the project and its interconnections and international spread really do make it ‘too big to fail’.

In a balanced conclusion, the author accepts the shortcomings involved, but points out these replicate the experience of similar programmes in the past; there is a certain inevitability in delays and rising costs given the complexity and multinational dependencies involved. Because of the urgency to replace the West’s ageing fleet of fourth generation combat aircraft and the imperative of the developing threat, he makes a compelling argument for the F-35 as an absolutely necessary capability, without a viable alternative, which is now proving its real worth as it matures in service.

Whilst I strongly recommend *Global Defense Procurement and the F-35 Joint Strike Fighter* as a case study of complex acquisition in general, and to provide an overview of the RAF’s most important combat capability in particular, it does have limitations. Because the programme is ongoing its dynamics are constantly changing, so any assessment will inevitably date almost as soon as it is published. From a UK perspective, the 2018 announcement of a Combat Air Strategy including the development of a ‘next-generation’ capability (‘Tempest’) in the 2040 timeframe, has obviously changed the landscape dramatically. Although the UK still aspires to buy 138 F-35B Lightnings, affordability must be questionable given the need to concurrently fund a new fighter. Tempest is also interesting as its stated objectives concerning UK sovereignty and industrial capability indicate that whilst the workshare involved in F-35 may be lucrative, it is not necessarily generating the expertise necessary to sustain UK aerospace for the future. There are clearly doubts about the ability to genuinely control and ‘own’ F-35 capability in terms of areas such as accessing software source codes; in fairness, a point the author covers well in relation to a discussion on the implementation of International Traffic in Arms Regulations.

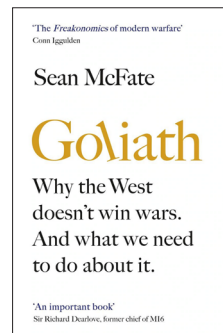
As well as a debate on numbers, there will inevitably be a discussion about the mix of variants in any future UK F-35 buy; there is obviously a strong case to buy the cheaper, and (in performance terms) more capable land-based F-35A once sufficient STOVL 'B'-models have been acquired for the carrier air wings. Chapman tells the story of the UK's switch from the F-35B to the conventional, carrier-launched 'C'-model and back again very well from a budgetary and political perspective; what is missing for a truly comprehensive account is the inter-service politics involved in the decision-making process, from which neither the RAF nor the RN emerge with much credit.

In summary, this book provides an excellent primer on the genesis and development of an essential capability which will underpin the hard edge of the UK's combat air power now and in the immediate future. Inevitably, there are minor errors in a work referencing so many sources (Meteor has an active not infra-red seeker, some RAF ranks are incorrect and those old enough to remember will be surprised that the Avro Shackleton was a fighter with a 640mph top speed!), but this book should be compulsory reading for all those with a professional interest in either the F-35 or the procurement and acquisition stream.



## Book Review

# Goliath: Why the West doesn't win wars. And what we need to do about it.



By Professor Sean Mcfate

**Publisher:** Michael Joseph (13th June 2019) (ISBN-13: 978-0241364031), 366 pages

Reviewed by Paul Stoddart

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**Biography:** Paul Stoddart served in the RAF from 1983 to 1991 as an aerosystems engineer officer and, following a short stint as a journalist on a car magazine, has worked in MOD since 1993. He worked on the Tornado successor study at Farnborough, managed the Harrier and Sea Harrier trials programmes at Boscombe Down and attended the Advanced Command & Staff Course at the Joint Services Command & Staff College. He is currently a scientific adviser at the Air Warfare Centre. He is a Fellow of the RAeS and a member of the RAeS Air Power Group committee.

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## Introduction

Sean McFate served in the US Army 82nd Airborne Division, left the service to gain a PhD and then worked for (according to the flyleaf biography) a 'major private military corporation'. He is currently a Professor of Strategy at the National Defense University in Washington, DC. Professor McFate is nothing if not blunt with his views. The book opens with the question "*Why has America stopped winning wars?*" and then claims that the USA has not achieved victory in conflict since 1945. He characterises Korea as "*an ongoing stalemate*", notes that Vietnam was reunified under communist rule and regards the US's actions in Afghanistan and Iraq as failures. He goes on to state "*Over the last seventy years, a disturbing trend has emerged: the West has forgotten how to win wars. It's obvious but no one talks about it, because the implications are too terrifying*". He dismisses the West's core military strengths of money and technology stating that this approach has been tried unsuccessfully for decades. He compares previous and current political and military



leaders to those of France in 1940 collapsing in the face of the German blitzkrieg, quoting the French historian Marc Bloch "...our leaders ...were incapable of thinking in terms of new war...".

He characterises Western militaries as prisoners of the conventional war strategy of World War 2, i.e. based on weight of kinetic effort and attrition, while claiming that the adversaries have moved on. The criticism of outdated or inadequate strategy is supported in the foreword where General Stanley McChrystal, US Army (retired) states that the West often applies a tactical focus at the expense of the strategic: "...our tactical successes gave both soldiers and policy-makers the false impression that our strategy was working. .... We were living one operation at a time; we celebrated our successes, but lacked wide enough perspective to clearly assess the impact we were having". General McChrystal was speaking of the fight against the so-called Islamic State but the point arguably applies in many other cases as well; America's failure in Vietnam being a prime example as well as the first stages of the NATO action against Serbia in 1999, Operation Allied Force.

Professor McFate criticises the continuing centrality, indeed reverence, accorded to Clausewitz in defence academies. He regards Clausewitzian, conventional state-on-state war as a thing of the past along with the notion that wars have distinct beginnings and endings. Instead, he states (the third of his ten rules) that "*there is no such thing as war or peace – both coexist, always*". There is much to be said for this point given the growing recognition of sub-threshold activities ("*shadow wars*") but it is debatable that direct state-on-state conflict will not occur again (Rule One: *Conventional war is dead*). His criticisms of big ticket assets, such as aircraft carriers and the F-35 Lightning, are trenchant and based on a view of their relative lack of utility against insurgent type foes, but he does not give enough weight to the possibility of once again having to face a peer level adversary where leading edge weapon systems will be essential. One interesting potential risk raised is that certain non-state entities, such as crime cartels and business corporations, now have greater wealth and influence than some countries and could choose to use military means to protect or further their interests. This would be a novel challenge to the West and one that merits study well in advance of the actuality occurring. Another interesting fact is that US special forces, though in continual heavy demand, get only 1.6% of the Pentagon's vast budget; a single aircraft carrier costs more than all these forces combined. Clearly, the balance between the various elements of modern western militaries need careful attention in terms of breadth of utility and cost effectiveness.

Though an academic, Professor McFate does not employ an academic tone in this work. Engaging and readable though it is, the book is often anecdotal and occasionally has a rather tabloid headline style. He is rightly suspicious of the claims made that new technologies will solve our sub-threshold and warfighting challenges; this reflexive belief in technology is widespread in Western militaries and should be balanced by emphasising the essential need to understand a problem fully before seeking a solution – especially one that involves buying yet more new equipment. On the other hand, he is rather too dismissive of the value of military

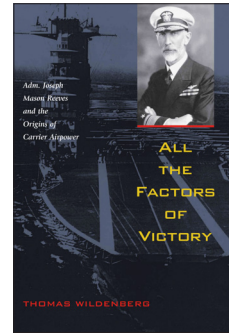
aircraft but presumably appreciated the mobility, situational awareness and fire support while he was serving in counter insurgency campaigns. (He implicitly acknowledges the value of air power when recounting its effectiveness in repelling a major attack by Russian Wagner Group mercenaries on US Delta Force rangers in Syria in May 2018). As for COIN campaigns, McFate explores the option that Western nations should 'outsource' military capability and use mercenary forces rather than deploy their own troops. It is a controversial notion, but not one to be summarily dismissed; as he suggests, faced with an insurgency, do not use a conventional army but instead "*beat the insurgents at their own game and start your own armed, social movement to compete with theirs*".

Professor McFate writes with the authority of one who has both experienced war directly and studied it in depth. While you might not agree with all his views, it is definitely worth reading this book so as to consider the challenges of and options for the modern world from a perspective that is notably different from that found in many of the defence world's standard studies. In his review in *The Times*, Sir Max Hastings disagrees with certain of Professor McFate's arguments but he also comments "*the British senior officers whom I know best regard much of McFate's thesis as a given*". Such views, whether considered rational, provocative or even iconoclastic, merit attention and this book is a useful contribution to an important debate.



## Book Review

# All the Factors of Victory: Admiral Joseph Mason Reeves and the Origins of Carrier Airpower



By Thomas Wildenburg

**Publisher:** US Naval Institute Press (15th January 2019) (ISBN-13: 9781682472996), 352 pages

Reviewed by Dr Steven Paget

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**Biography:** Dr Steven Paget is the University of Portsmouth's Director of Academic Support Services at Royal Air Force College Cranwell. Prior to that, he was a lecturer in strategy and operations at the New Zealand Defence Force (NZDF) Command and Staff College and an NZDF Teaching Fellow at the Centre for Defence and Security Studies, Massey University.

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## Introduction

Admiral Joseph Mason Reeves, the first United States Navy (USN) aviation-qualified officer to reach flag rank, has been referred to as 'the father of carrier warfare'. It is somewhat ironic that an officer that achieved public notoriety during his service has been subjected to such limited scholarly attention in the historiography. Thomas Wildenberg should be commended for shining further light on Admiral Reeves – described by the book's author as 'an extremely talented officer, well versed in all aspects of naval science' (p. 265) – given his pivotal influence on the development of US naval aviation. The contribution of Reeves has perhaps been undervalued by his pioneering work on naval aviation being conducted during peacetime, even though the legacies of his efforts were evident during the Second World War. His eventual specialism in naval aviation was mutually beneficial. Reeves undoubtedly helped to advance carrier aviation, but the increasing prominence and importance of naval aviation may also have helped to progress his career.

The book examines the length of Reeves' career, involving a range of sea and shore appointments, and spanning the Spanish-American War, the First World War and the Second World War. The detailed examination of each of his appointments buttresses Wildenberg's conclusion that innovations by Reeves 'laid the foundations for all of the major tenets of modern carrier doctrine' (p. 266). In *All the Factors of Victory*, Wildenberg has not only produced a detailed and informative biography of Reeves, but a window into the history of the USN during a crucial time in its development. The book provides insights into life at the United States Naval Academy in Annapolis in the late 19th Century and touches briefly on significant issues such as the intersection of civilian and military aviation and the importance of competition in the aviation industry. *All the Factors of Victory* also does an excellent job of detailing Reeves' navigation of the potential minefield of career progression. While Reeves is the focus of the book, Wildenberg weaves the contributions and innovations of other officers (both well known and less so) into the narrative, but could perhaps have examined the wider trends in naval aviation in greater detail for context.

Whilst the book discusses a wealth of material of historical interest, it is also replete with anecdotes and examples of contemporary relevance, aside from the obvious issue of the employment of carrier air power. As Wildenberg notes, Reeves' career was underpinned by, and a testament to, the three equally important pillars: education, training and experience. In addition, the value of wargaming is evident from the insights that Reeves gained during his time at the Naval War College. Reeves' career was built on innovation as he sought to rectify deficiencies and introduce enhancements in all of his posts throughout his career. Indeed, Reeves settled for nothing short of excellence and applied the same standards to his subordinates as well as to himself. In both the development of the USN's aviation capability and the advancement of Reeves, the importance of media relations and positive public relations is evident. Perhaps one of the most important takeaways for practitioners, which appears in the preface and explains, in part, why Reeves may have received comparatively scant academic attention, is the importance of writing. Wildenberg notes that despite being a brilliant orator, Reeves left 'few writings and no personal papers' (p.x).

The book is well researched and Wildenberg weaves together historical records from a range of archives. The author is able to piece together a convincing picture yet is sometimes compelled to rely on assumptions given the paucity of material relating to certain issues. It could be argued that while some assertions are stretched too far occasionally, such as when Wildenberg speculates as to what may have happened if Reeves had been in command at Pearl Harbor on 7 December 1941, most assumptions are reasonable and logical.

Overall, this is a well-researched and convincingly argued book that should find a home in both professional and personal libraries. It will be of interest to both practitioners and scholars of air and naval power and is particularly pertinent for British readers given the re-introduction of aircraft carriers into the Royal Navy.

# RAF Historical Society Call for Papers

## Overview

The Royal Air Force Historical Society was established in 1986 to provide a lens through which the study of the history of the Service might be focused. It does this by organising lectures and seminars at which those interested in the history of the RAF have the opportunity to meet those who participated in the evolution and implementation of policy. The Society believes that these events make an important contribution to the permanent record. RAF Historical Society website:

<https://www.rafmuseum.org.uk/about-us/partners/raf-historical-society.aspx>.

## Membership

Membership is open to anyone with an interest in RAF history, irrespective of whether they have had any direct connection with the Service. By being a member of the Society you will receive the three journals produced each year and be invited to attend seminars designed to explore specific themes – all in all, this will give you access to a rich source of information about various studies undertaken by academics, serving personnel and those simply with an interest in RAF history. You will also be invited to the Society's AGM held every year in the RAF Club where you will be given the opportunity to voice your opinions on how the Society is managed. Membership costs £18 per year. For more details you can email the Membership Secretary (Wg Cdr Colin Cummings RAF (Retd)) at [colincummings@tiscali.co.uk](mailto:colincummings@tiscali.co.uk).

## Henry Probert Bursary – Call for Applications

Air Commodore Henry Probert MBE was one of the most eminent authorities on the history of the RAF, head of the RAF's Air Historical Branch, a founder member of the RAF Historical Society and, whilst serving, the RAF's Director of Education. Following his death, the RAF Historical Society endowed a bursary in Air Commodore Probert's memory to encourage scholarly research which is awarded by the RAF Historical Society Committee on a regular basis to those students who intend to add to the historiography of the RAF through their studies. Enquiries should be directed to the Directorate of Defence Studies (telephone 01793 788868 or email [enquiries.dds@da.mod.uk](mailto:enquiries.dds@da.mod.uk)). The next deadline for applications is 3 February 2020.

## Two Air Forces Award – Call for Papers

In 1996, the Royal Air Force Historical Society established the Two Air Forces Award in collaboration with the United States Air Force Historical Foundation. This is presented annually in recognition of outstanding academic work by a serving member of the British military or MOD civil servant adjudged to have significantly contributed to the historiography of air power. Entries are welcomed from any serving military or MOD Civil Service personnel for any air power-related essay to a maximum of 7,000 words. For more details, please contact the Directorate of Defence Studies (telephone 01793 788868 or email [enquiries.dds@da.mod.uk](mailto:enquiries.dds@da.mod.uk)). The next deadline for applications is 17 February 2020.



**T**he Air & Space Power Association (ASPA) is an authoritative voice and platform for discussion and debate on how air power influences today's world and its relevance to the future.

Our mission is to foster a better understanding of the military exploitation of the air and space environment in order to maximise the efficiency of its use and the application of emerging technologies. The ASPA's aim is to grow air power ambassadors and to provide a focal point for interaction between air power practitioners and their industrial partners and other relevant organisations and individuals.

Established in 1947, the Association's membership comprises highly regarded individuals with a wealth of experience in the air and space power domain and is open to individuals, businesses, military units, consultants and academics. Indeed, anyone who has an interest in air and space power.

Members include serving and retired members of the UK's Armed Forces and from overseas, those engaged in the Media and Communication Directorates of the MOD, Members of Parliament, academics with aviation or associated aviation/defence interests, representatives of the aerospace and defence industries and aviation/defence media.

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ISSN: 1463-6298

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