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Combat Air Choices for the UK Government

Justin Bronk



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Executive Summary

- Combat air is typically the UK government's first tool of choice when the use of armed force is required overseas. This will increasingly require the ability to operate in the face of modern integrated air defence systems, as systems such as the Russian S-300/S-400 series and Chinese HQ-9 proliferate widely.
- A majority of the available conventional firepower for the armed forces is – and will likely remain – air-delivered,¹ so the viability of combat air as a whole must be maintained if the UK wishes to remain a credible warfighting power.
- Combat air supports around 46,000 jobs, many highly skilled, and generates approximately 80% of the UK's annual defence export orders of around £6 billion.² The sector must generate new intellectual property to remain viable. This requires new design work.
- The UK's Combat Air Strategy, which launched in 2018, has four core pillars: to keep the Typhoon fast jet fleet capable and relevant at least until 2040; to continue to build up and mature the joint RAF/RN F-35 force; to develop a replacement capability for Typhoon by 2040 via Team Tempest; and to maintain a globally competitive domestic combat air industry. These ambitions are interdependent to a significant degree.
- Under current budgetary conditions, these ambitions are not affordable without major changes to the makeup of the RAF's whole force structure, as well as significant changes to the defence-industrial model that currently underpins the UK defence aerospace sector.
- Political guidance around the need to plan for high-intensity, state-on-state warfighting is needed from the government as part of the Integrated Review, in addition to clarity on the financial resources which defence can draw on to try to meet policy ambitions.
- Even if a political decision is made to deprioritise regenerating operational credibility against Russian forces in a NATO Article 5 context for the armed forces as a whole, credible RAF suppression/destruction of enemy air defences (SEAD/DEAD) capabilities will likely be a requirement to ensure sovereign freedom of action overseas and a leading role within coalition operations in the coming decades.
- While it remains an operating assumption for many, the outcome of the Team Tempest next-generation combat air development programme is not necessarily going to involve a new (optionally) piloted fast jet fleet to directly replace Typhoon. If that ambition is the choice made, it will have major budget implications for an already stretched combat air equipment programme between 2024 and 2040.
- If warfighting capability between 2020 and 2040 is more important as a planning consideration, the path of least resistance would be to purchase as many of the original 138 F-35 ambition as the equipment plan can bear during the 2020s. If significant additional funding is found by cutting other capabilities, there is a strong argument for

1. For an overview of joint force long-range precision fires, see Jack Watling, 'The Future of Fires: Maximising the UK's Tactical and Operational Firepower', *RUSI Occasional Papers* (November 2019).

2. Ministry of Defence, 'Combat Air Strategy: An Ambitious Vision for the Future', 16 July 2018, p. 13.

purchasing land-based F-35As after the initial 48 carrier-capable F-35Bs. The F-35A is cheaper to purchase and operate, with longer range and better payload, as well as a much larger international user base. If purchased in significant numbers, then overall costs would be reduced compared to a large pure F-35B fleet.

- Without greatly increased defence spending, F-35 purchases at scale beyond 2024 remain financially incompatible with a separate (optionally) piloted fast jet-centric Tempest programme to replace Typhoon, even if some additional combat air funding can be found through cuts elsewhere in the force structure.
- Explicitly designating Tempest as an unmanned combat aerial vehicle (UCAV) programme could help avoid this deadlock to a degree. A Tempest UCAV would allow the generation of new design intellectual property (IP) for industry, and be inherently cheaper to develop, procure and sustain for a given level of combat power. Cost savings derive from the significantly reduced airframe complexity, fleet size, training, testing and certification requirements compared to a piloted aircraft development effort.
- Without the need to rotate squadrons, airframes and personnel for training, maintenance, deployment and rest cycles, UCAVs offer significantly more operationally ready airframes from a given fleet size. As such, a UCAV-centric Tempest programme could generate comparable operational combat strength by 2040 while delivering fewer than half of the airframes needed for a viable piloted solution.
- Making a UCAV-centric programme viable for an industry that has typically relied on large production volumes, support and maintenance contracts at scale and large numbers of flight hours for long-term profitability will require a new and more streamlined financial model. However, the alternative is likely to be long-term relegation of UK defence aerospace to sub-contractor status within larger US- or European-led programmes due to funding constraints.
- Procuring as many F-35s as the budget can sustain, alongside a limited-scale but ongoing and iterative UCAV programme under Tempest throughout the 2020s and 2030s, could provide a combat air roadmap for warfighting (especially SEAD/DEAD) credibility until 2040 and beyond. It would also help to sustain critical defence-industrial IP generation and manufacturing capabilities, albeit at a reduced scale, and de-risk Typhoon mid-life upgrade and sustainment.
- This would still require a significant uplift in combat air funding which, in light of national resource constraints, would probably imply significant cuts to existing RAF mobility and ISTAR fleets. The latter are generally not survivable in contested airspace but perform highly valuable work in more common operational scenarios. As such, this strategy would be a choice to invest in state-on-state warfighting capacity, to the detriment of important capabilities for lower-intensity operations.
- The government could decide to pursue a piloted Tempest programme at scale to protect jobs and stimulate the economy after the coronavirus pandemic, and such a strategy is within the UK's means. However, it would need to be funded from outside the core defence budget to avoid serious damage to the already stretched ability of military combat air planners to meet operational and strategic requirements with available resources during the 2020s and 2030s.

Introduction

THE UK FACES fundamental questions about its identity, global strategy and ambitions as a medium power, having left the EU against a backdrop of an economically devastating global pandemic, an increasingly unpredictable US administration that has abandoned many of the previously assumed tenets of the international system, and aggressive competition by major powers in the shape of Russia and China. Under the banner of 'Global Britain', the government has made clear its ambition to remain an influential actor able to exert soft and hard power around the world, while also revitalising its longstanding commitments to both NATO and the so-called 'special relationship' with the US.¹

At the heart of the UK's relationships within NATO, and with the US specifically, is an ambition to remain the ally of choice for the US as a 'tier one' military.² However, the US Department of Defense is increasingly focused on the growing military threat from China in the Indo-Pacific, at the expense of traditional areas of focus in the Middle East and Europe.³ President Donald Trump has repeatedly demanded that European NATO members do more to modernise and enhance defence capabilities in Europe itself, in order to reduce the burden placed on US forces by the threat of Russian aggression against the Alliance's eastern flank.⁴ At a national strategy level, therefore, the UK is unlikely to reduce overall defence spending (at least as a proportion of GDP), since that would weaken its position as both a global power projection partner for the US, and within NATO. However, at 2% of pre-coronavirus GDP, the UK armed forces are struggling with an 'overambitious and underfunded' equipment programme,⁵ long-overdue modernisation requirements from the British Army and Royal Navy, and an incoherent force

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1. For collected speeches and documents on 'Global Britain' ambitions, see Foreign and Commonwealth Office, Cabinet Office and Prime Minister's Office, 'Global Britain: Delivering on Our International Ambition', last updated 29 September 2019, <<https://www.gov.uk/government/collections/global-britain-delivering-on-our-international-ambition>>, accessed 28 May 2020.
 2. David Bond, 'Defence Secretary Pledges to Maintain UK Status as Tier One Power', *Financial Times*, 17 December 2018.
 3. For more details, see Justin Bronk, *The Future of NATO Airpower*, Whitehall Paper 94 (London: Taylor and Francis, 2020).
 4. See, for example, Julie Hirschfeld Davis, 'Trump Warns NATO Allies to Spend More on Defense, or Else', *New York Times*, 2 July 2018; Ewen MacAskill and Pippa Crerar, 'Donald Trump Tells Nato Allies to Spend 4% of GDP on Defence', *The Guardian*, 11 July 2018; David M Herszenhorn, 'Trump Threatens to Punish Germany over Military Spending', *Politico*, 4 December 2019.
 5. Georgina Bailey, 'Ben Wallace Interview: UK Defence Isn't Fit for Purpose – Our Armed Forces Must Adapt to 21st Century Threats', *The House Magazine*, *Politics Home*, 19 June 2020, <<https://www.politicshome.com/thehouse/article/ben-wallace-interview>>, accessed 23 June 2020.

structure that is neither well-optimised for NATO deterrence against Russia, nor for sustained operations far afield at any significant scale.⁶

During the upcoming Integrated Review, the government will either have to significantly raise defence spending or make some hard decisions on what the armed forces are optimised for in the 2020s and 2030s, as well as the future of the UK's military aerospace industry within the broader prosperity agenda.

Against this backdrop, this paper sets out to examine the choices facing those attempting to narrow down options for the future of UK combat air through 2020 and 2021 in the context of renewed budgetary pressure on defence and the Integrated Review. How can a coherent force be generated and sustained during the next two decades, while also maintaining a viable domestic combat air design and manufacturing capability for the long term? It is intended to help inform and suggest options for policymakers, rather than present findings in the format of a more traditional research paper.

Combat air, defined as 'aircraft, manned or unmanned, whose prime function is to conduct air-to-air and/or air-to-surface combat operations in a hostile and/or contested environment' is typically the UK government's first tool of choice when the use of armed force is required overseas – whether that be reassurance and deterrence deployments to Eastern Europe since 2014, Libya in 2011 or Operation *Shader* to defeat the Islamic State in Iraq and Syria since 2014.⁷ In terms of equipment, doctrine and force structure, the British Army and Royal Navy have also been largely configured with assumed air superiority – or at least access to large-scale air support – in mind since the end of the Cold War. This has not been a serious issue in the wars which the UK has fought during those two decades, but with a rapid proliferation of advanced ground-based air defence systems and the return of great power competition as a potential threat in Europe, the Middle East and the Pacific, it is no longer a safe assumption.⁸

Short of a major re-equipment of the British Army and Royal Navy with large-scale long-range precision fires capabilities, the majority of the armed forces' available conventional firepower will remain air-delivered,⁹ so the viability of UK combat air as a whole must be maintained against those threats which the government determines are within the Ministry of Defence's (MoD) responsibility. Combat air is also a cornerstone of the UK defence-industrial base, supporting around 46,000 jobs and generating approximately 80% of the UK's annual defence

6. On the Equipment Plan deficit, see National Audit Office, 'The Equipment Plan 2019 to 2029', HC 111, Session 2019–20, 27 February 2020.

7. Ministry of Defence (MoD), 'Combat Air Strategy: An Ambitious Vision for the Future', 16 July 2018, p. 11.

8. See Justin Bronk, 'Modern Russian and Chinese Integrated Air Defence Systems: The Nature of the Threat, Growth Trajectory and Western Options', *RUSI Occasional Papers* (January 2020).

9. For an overview of joint force long-range precision fires, see Jack Watling, 'The Future of Fires: Maximising the UK's Tactical and Operational Firepower', *RUSI Occasional Papers* (November 2019).

export orders of around £6 billion.¹⁰ For the sector to remain viable in the medium and long term, it must generate new intellectual property to leverage as part of international consortia. This requires new design work with a sufficiently robust order book for resulting combat air systems to make them affordable and competitive on the international market.¹¹

The following chapters will lay out the current state of UK combat air, followed by an assessment of the Tempest next-generation combat air programme in that context. The third chapter will explain why future combat air choices are largely dependent on the answers to core questions about the UK's geopolitical strategy, which can only be answered by the Integrated Review, with a subsequent chapter on some of the financial realities facing combat air policymakers. The conclusion offers policy recommendations intended to illustrate a potential way to achieve at least some of the conflicting combat air policy priorities.

This paper draws on the author's long-term research into the Typhoon and F-35, Russian and Chinese threat systems, and broader NATO airpower policy questions conducted since 2015 as part of several research projects.¹² It also draws on focused interviews from the past two years, as well as two closed roundtable discussions held at RUSI in September 2019 and January 2020 with subject-matter experts from the armed forces, government and industry. Due to the sensitive commercial and security nature of the subject matter, the roundtable discussions were conducted under the understanding that they were for background information. Thus, no direct attributions to individual participants will be made.

10. MoD, 'Combat Air Strategy', p. 13.

11. A point repeatedly emphasised by representatives from multiple defence original equipment manufacturers (OEMs) in closed roundtable sessions on future combat air choices at RUSI, London, 24 September 2019 and 20 January 2020.

12. See, for example, Justin Bronk, 'Maximising European Combat Air Power: Unlocking the Eurofighter's Full Potential', *Whitehall Report*, 1-15 (April 2015); Justin Bronk, 'Maximum Value from the F-35: Harnessing Transformational Fifth-Generation Capabilities for the UK Military', *Whitehall Report*, 1-16 (February 2016); Justin Bronk, 'Next Generation Combat Aircraft: Threat Outlook and Potential Solutions', *RUSI Occasional Papers* (November 2018); Bronk, 'Modern Russian and Chinese Integrated Air Defence Systems'; Bronk, *The Future of NATO Airpower*.

I. The Current Force

Typhoon

Fast jets are the core combat power of the RAF and Fleet Air Arm. These comprise around 145 Typhoon FGR.4 multirole fighters and will include 35 F-35B Lightning II multirole stealth fighters by 2022, rising to 48 by the end of 2024.¹³ Although the UK remains officially committed to purchasing 138 F-35s, the orders confirmed in the equipment plan at the time of writing will result in an inventory of 48 aircraft by 2024.¹⁴ Combat air already accounts for a significant proportion – £17.1 billion of the planned £188 billion 10-year equipment plan as of 2019.¹⁵ In 2018, the government also announced its intention to develop a new combat air capability to replace the Typhoon fleet through the late 2030s and early 2040s under the banner of Team Tempest.¹⁶ In addition to providing operational capability to replace Typhoon, the Tempest programme is also central to the government’s policy of retaining a national defence-industrial capacity to design and manufacture combat aircraft and associated sensors and weapons systems as a strategic capability.

The Typhoon force currently comprises seven frontline squadrons (1, 3, 6, 12, II, IX, and XI Squadrons), as well as the operational conversion unit (29 Squadron), and the test and evaluation squadron (41 Squadron). All are based at either RAF Lossiemouth in Scotland or RAF Coningsby in Lincolnshire, with units generating crews on a rotational basis to maintain the four aircraft permanently deployed as No. 1435 Flight at RAF Mount Pleasant in the Falkland Islands. This represents a relatively large number of squadrons to generate and sustain over the remaining life of the Typhoon force from a fleet of just over 140 aircraft. The RAF’s target of an at least

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13. The UK has 17 F-35Bs on order for delivery between 2020 and 2022, which will join the 18 already delivered. Those already delivered are based at RAF Marham in the UK, although a small number will remain based at Marine Corps Air Station Beaufort in South Carolina for testing and training purposes. See MoD, ‘UK to Double F-35 Fleet with 17-Jet Order, Defence Secretary Announces’, 15 November 2018, <<https://www.gov.uk/government/news/uk-to-double-f-35-fleet-with-17-jet-order-defence-secretary-announces>>, accessed 27 April 2020. The RAF retired approximately 15 of its oldest Tranche 1 Typhoons, especially the non-combat-capable twin seat T.3 variants in 2019, due to airframe fatigue and high maintenance costs. Since the UK received a total of 160 Typhoons, this results in a current inventory of approximately 145.
 14. MoD, ‘The Defence Equipment Plan 2019: Financial Summary’, 27 February 2020, p. 37; House of Commons Defence Committee, ‘Unclear for Take-Off? F-35 Procurement: Responses to the Committee’s Second Report’, Fifth Special Report of Session 2017–19, HC 845, paras 6–7.
 15. MoD, ‘The Defence Equipment Plan 2019’, pp. 6, 30.
 16. Penny Mordaunt, ‘Combat Air Strategy Update: Written Statement - HCWS1778’, MoD, 22 July 2019, <<https://www.parliament.uk/business/publications/written-questions-answers-statements/written-statement/Commons/2019-07-22/HCWS1778/>>, accessed 6 May 2020.

50/50 ratio between live flying training and simulator training goes some way towards making this situation more sustainable, as it reduces the flying load per pilot on physical airframes.¹⁷ Nonetheless, it does mean that the UK will continue to use up airframe fatigue hours far faster than other Eurofighter Typhoon operators, and also has a very limited capacity to absorb aircraft losses – either through accidents or in combat – before the effective frontline strength of the Typhoon force would start to diminish. The concentration of all Typhoon squadrons on two main operating bases which lack ground-based air defences also means that the force is vulnerable to attack on the ground in the event of a conflict with a peer competitor with long-range precision strike capabilities such as Russia.

The more modern Tranche 2 and 3 Typhoons have been upgraded with full multirole mission capabilities under the umbrella of Project *Centurion*, meaning they can deliver precision strikes with Paveway IV GPS and laser-guided bombs, Brimstone 2/3 anti-armour and low-collateral strike missiles, and standoff cruise missiles in the shape of the Storm Shadow, all while carrying out self-escort and strike package protection duties with AMRAAM, Meteor and ASRAAM air-to-air missiles. This makes them highly capable against modern air threats, including the most up-to-date systems deployed and exported by peer competitors. They are also able to conduct heavy and precise direct and standoff strike missions against ground forces in permissive or semi-permissive airspace. The older Tranche 1 aircraft have a limited strike capability, but are now being employed exclusively in the air-to-air and aggressor training support roles using AMRAAM and ASRAAM.

Although a best-in-class mechanically scanned radar, the CAPTOR-M which equips all RAF Typhoons is significantly less capable in terms of range, target identification, anti-jamming resilience and low-probability of intercept/detection (LPI/LPD) techniques compared to active, electronically scanned array (AESA) types. The Eurofighter consortium has developed an AESA upgrade for Typhoon, called CAPTOR-E, which will equip export Typhoons for Kuwait and Qatar, as well as Germany's Tranche 2 and 3 fleets, in addition to their new Quadriga order of 38 airframes to replace their ageing Tranche 1s.¹⁸ So far, the plan to eventually upgrade some of the RAF's Tranche 2 and 3 aircraft with an advanced version of CAPTOR-E, known as European Common Radar System 2 (ECRS Mk.2), is not fully funded and remains uncertain in terms of numbers and timeframe.¹⁹ This is important from both a lethality and survivability standpoint –

17. For more details, see Defence Equipment and Support, 'Gladiator Heralds a New Dawn for Fighter-Jet Training', 5 March 2020, <<https://des.mod.uk/fighter-heralds-a-new-dawn-for-fighter-jet-training/>>, accessed 6 May 2020.

18. Airbus, 'Airbus Signs Contract for Integration of 115 New Eurofighter ESCAN radars', 26 June 2020, <<https://www.airbus.com/newsroom/press-releases/en/2020/06/airbus-signs-contract-for-integration-of-115-new-eurofighter-escan-radars.html>>, accessed 26 June 2020; Jon Lake, 'New Beginnings for the Eurofighter Typhoon', *AINOnline*, 24 December 2019, <<https://www.ainonline.com/aviation-news/defense/2019-12-24/new-beginnings-eurofighter-typhoon>>, accessed 7 May 2020.

19. Andrew Chuter, 'Royal Air Force Typhoon Jets to Receive Key Sensor Upgrade', *C4ISRNet*, 8 August 2019, <<https://www.c4isrnet.com/global/europe/2019/08/08/royal-air-force-typhoon-jets-to-receive-key-sensor-upgrade/>>, accessed 7 May 2020.

as currently equipped, the Typhoon fleet would need to stand off hundreds of kilometres from the most modern long-range surface-to-air missile (SAM) threats such as the Russian S-400 and S-300V4 or risk heavy losses.²⁰

While Typhoon can fire the long-range Storm Shadow standoff cruise missile from such ranges, the aircraft's own sensors cannot provide targeting data against threats from so far back, and so would have to rely on real-time target data provided by other assets further forward.²¹ By nature, standoff weapons such as Storm Shadow with ranges of many hundreds of kilometres are also large and expensive, resulting in relatively limited stockpile quantities. The electronic warfare modes planned for ECRS Mk.2 would allow Typhoon to penetrate closer with reduced risk, quite aside from the situational awareness and lethality boost that the AESA radar would bring to all mission sets.²² ECRS Mk.2 is also intended to greatly improve the ability of the Typhoon to identify unknown aircraft at very long ranges when the latter are not transmitting transponder or identification friend or foe (IFF) codes. This is important for enabling the exploitation of the extremely long range of the new Meteor missile under most rules of engagement (ROE).

Project *Janus* is the successor programme to *Centurion*, and includes planned datalink, sensor, weapons and avionics modernisation to maintain the effectiveness of the Typhoon fleet out to the planned 2040 out-of-service date for the Tranche 2s and 3s, and 2035 for the remaining Tranche 1s.²³ However, the Tranche 1s are significantly less capable especially in terms of upgrade potential, and are also likely to become increasingly expensive to operate from the late 2020s. Without any spare funds to replace these aircraft during the 2020s with new-build Typhoons, as Germany is doing for its Tranche 1s, or with another solution such as additional F-35As, retiring these aircraft before 2035 will further reduce financially irreplaceable combat mass, and increase the operational demands and wear rate on the remaining Tranche 2 and 3 aircraft.²⁴

F-35 Lightning II

The F-35B is the complementary and even more advanced stablemate to the Typhoon, but it is very different in nature. For a start, the limited number of F-35Bs currently delivered or on order are double-hatted in that they are central to the planning assumptions of both the Royal Navy for its carrier strike groups, and the RAF for suppression/destruction of enemy air defences (SEAD/DEAD), penetrating ISTAR for other joint force elements, and strike operations within

20. For more information on modern Russian and Chinese surface-to-air missile threats, see Bronk, 'Modern Russian and Chinese Integrated Air Defence Systems'.

21. For details on Storm Shadow, see MBDA, 'Storm Shadow/SCALP', <https://www.mbda-systems.com/?action=force-download-attachment&attachment_id=16702>, accessed 26 June 2020.

22. Author telephone interview with former RAF Typhoon instructor and current industry subject-matter expert, 13 May 2020.

23. *Ibid.*

24. Daniel Darling, 'German Defense Minister Makes Tornado Replacement Plans Official', Defense & Security Monitor, 22 April 2020, <<https://dsm.forecastinternational.com/wordpress/2020/04/22/german-defense-minister-makes-tornado-replacement-plans-official/>>, accessed 24 June 2020.

the coverage of modern ground-based air defence networks. The aircraft itself is a very low observable (VLO) design, meaning it is difficult for fire control radars to detect when carrying its weapons internally; a property which is at the core of its ability to operate sustainably and effectively within heavily contested airspace.

The other standout capability of the F-35 is its ability to gather huge amounts of information about the surrounding battlespace, using a range of both active and passive sensors to build a single picture for the pilot – a technique known as sensor fusion. This involves automatic real-time cross-cueing, comparison and cross-referencing of sensor inputs from sensors in multiple parts of the electromagnetic spectrum on all aircraft within a formation, allowing more stringent ROE-compliant target detection and identification capabilities compared to previous types, as well as unmatched in-cockpit situational awareness. This situational awareness works with the VLO properties of the airframe, helping an F-35 pilot to adapt to hostile force activities in real time to minimise the likelihood of detection and maximise mission effectiveness.

The F-35's AN/APG-81 radar is an AESA type which features advanced LPI/LPD capabilities to allow it to rapidly search for ground and airborne targets and engage them if necessary, while remaining very difficult for hostile forces to detect.²⁵ This AESA radar, coupled with the impressive processing power available within the F-35's avionics, also means it has a great deal of potential electronic warfare capacity, notably enhancing its potential self-protection options and SEAD capabilities.²⁶

The F-35 is produced in three variants: the conventional take-off and landing 'A' for the US Air Force and most export customers; the short take-off and vertical landing (STOVL) 'B' for the US Marine Corps, UK and Japan; and the catapult take-off but arrested recovery (CATOBAR) 'C' for the US Navy. The UK has firmly committed to 48 F-35Bs by 2024 as part of the current equipment plan, but the numbers and variant mix beyond that remain uncertain despite 138 F-35Bs technically remaining the official UK position.²⁷ The *Queen Elizabeth*-class aircraft carriers require the STOVL F-35B due to their configuration with a 'ski-jump' take-off ramp and lack of arrestor cables. However, this variant has a shorter range, is more expensive and more mechanically complex, and has a smaller internal weapons capacity than the F-35A. This has led to suggestions that the RAF should acquire F-35As once sufficient F-35Bs are in service to form a core carrier strike air group.²⁸ All F-35 variants are specifically designed to operate against modern ground-based air defence network-equipped adversaries. They are also very survivable

25. Author interviews with operations analysis and avionics experts during visit to F-35 production facility in Fort Worth, Texas, February 2019.

26. For more in-depth information about the F-35 within the broader UK armed forces context, see Bronk, 'Maximum Value from the F-35'.

27. House of Commons Defence Committee, 'Unclear for Take-Off?', paras 6–7.

28. See, for example, Deborah Haynes, 'Royal Navy and RAF Locked in Dogfight Over New Jets that Cannot Fly from Warships', *Sky News*, 1 December 2018; Nicholas Drummond, 'Why the RAF Needs the F-35A JSF As Well As the F-35B', *UK Land Power*, 7 December 2018, <<https://uklandpower.com/2018/12/07/why-the-raf-needs-the-f-35a-jsf-as-well-as-the-f-35b/>>, accessed 18 May 2020.

against aerial threats as a result of their situational awareness and VLO design, despite lacking the high-speed and high-altitude performance, missile carriage capacity and agility of the air-superiority-focused Typhoon.

The F-35 is currently the only combat air asset which the UK can field that is capable of sustained operations within missile-engagement range of modern air defence networks without a high risk of losses. As such, its main limitation for the UK is that, with current numbers, there will be heavy dependence on a very limited number of F-35Bs for a broad range of potentially highly geographically dispersed missions in support of all the services. The Royal Navy is dependent on the aircraft for the fixed-wing component of Carrier Strike whenever the *Queen Elizabeth* or *Prince of Wales* deploy, and the RAF and broader joint force for SEAD/DEAD and strikes in support of ground forces against modern state opponents prior to that SEAD/DEAD campaign being won. It will also be called on increasingly as a force multiplier in all joint operations around the globe as defence attempts to extract maximum value from its combination of survivability and ISTAR generating capacity. The F-35 currently represents the sole penetrating ISTAR asset which the UK can field against state opponents with modern air defence systems.²⁹ The basic need to find, identify, track and target enemy forces before they can be hit effectively, coupled with the ability of modern air defences to force the RAF's existing traditional ISTAR assets such as RC-135W and Sentinel R.1 back beyond the effective range of their sensors, means that penetrating ISTAR will be critical in future high-intensity conflicts.

In the absence of other penetrating ISTAR capabilities, F-35 sortie availability and datalink connectivity is likely to be the key factor in determining the effectiveness of long-range precision fires in all domains in the event of a high-intensity conflict. However, despite being advanced, each F-35 can be in only one place at a time, and as a relatively immature VLO aircraft of unprecedented complexity, frontline availability will likely remain lower as a percentage of the fleet compared to more traditional fast jets.³⁰

In terms of long-term combat effectiveness, the VLO advantages of the F-35's airframe will inevitably be slowly eroded over time by continuing advances in hostile sensor technologies. However, the ability to track an aircraft within certain parameters – for example, by the use of lower frequency, longer wavelength or coherent passive location radar techniques – does not

29. Penetrating ISTAR refers to the ability to gather intelligence, surveillance and targeting information on hostile forces from within airspace which is heavily contested by ground- and/or air-based threats without getting shot down.

30. For a discussion of ongoing F-35 availability issues, see Oriana Pawlyk, 'US F-35 Fighter Jets are All Still "Below Service Expectations" for All the Services that Have Them', *Business Insider*, 15 November 2019; Garrett Reim, 'F-35 Full Mission Capability Rate Only 27% Due to Parts Shortages', *FlightGlobal*, 26 April 2019, <<https://www.flightglobal.com/fixed-wing/f-35-full-mission-capability-rate-only-27-due-to-parts-shortages/132447.article>>, accessed 18 May 2020; Colin Clark, 'F-35 Readiness Rates Soar, from 55% to 73%; Price Drops 12.8%', *Breaking Defense*, 29 October 2019, <<https://breakingdefense.com/2019/10/f-35-readiness-rates-soar-from-55-to-73-price-drops-12-8/>>, accessed 18 May 2020.

necessarily translate into an ability to successfully guide a weapon on to that aircraft before it can kill the shooter or break tracking.³¹ In other words, while it will get harder to completely hide the F-35 from hostile sensors over time, it will still have a major advantage over non-VLO platforms in being very difficult to detect in the X and Ku bands of the radar spectrum. The latter are typically used by fire control radars and missile seeker heads due to their high resolution over range versus aperture size and power properties.³² Furthermore, the increasing capabilities of sensors will also make other aircraft correspondingly easier to target over longer ranges, so VLO platforms will still be able to get closer to threats than traditional platforms. Tactics and concepts of employment will nonetheless have to change as medium- and high-altitude passive stealth becomes less viable against the highest-tier threats, drawing on the situational awareness generated by the F-35, as well as its nascent electronic and cyber attack capabilities.³³

MQ-9/9B Reaper/Protector

While far removed from fast jets in many respects – not least being an unmanned, subsonic airframe unsuitable for operations in contested airspace – the MQ-9 Reaper has provided a substantial proportion of the RAF's strikes and ISTAR missions in Afghanistan, Iraq and Syria since its acquisition in 2007.³⁴ The MQ-9 Reaper and its planned successor, the MQ-9B Protector, offer far higher endurance on station than a fast jet could,³⁵ at a significantly lower airframe operating cost and while carrying a range of highly capable sensors and precision strike munitions.³⁶ They are typically deployed as 'orbits', where several airframes and crews are used in rotation to ensure non-stop ISTAR and, if necessary, strike coverage of a given geographical area for extended periods.

Despite being physically unmanned, the MQ-9 series of remotely piloted aerial systems (RPAS) are nonetheless 'one of the most manpower-intensive aircraft to operate' when looked at as a whole.³⁷ This is due to the need for multiple three-person crews to rotate every eight hours to maintain constant orbits and the huge volume of data that each one generates. This places a correspondingly heavy burden on the RAF Intelligence Corps (and other agencies) that sort through, process and develop that data into actionable intelligence. These assets are a huge force multiplier in terms of providing friendly or allied ground forces with persistent overhead

31. Author interview with F-22 aircrew, London, 3 May 2016.

32. For a more detailed overview, see radartutorial.eu, 'Waves and Frequency Ranges', <<https://www.radartutorial.eu/07.waves/Waves%20and%20Frequency%20Ranges.en.html>>, accessed 12 June 2020.

33. Author interviews with civilian (former fighter pilot) SME, Washington, DC, 12 July 2019.

34. See, for example, PJHQ J9 FOI Secretariat, Response to FOI Request, FOI2015/08518, 12 November 2015, <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/478546/20151112-FOI2015-08518_Upload.pdf>, accessed 19 May 2020.

35. For instance, the MQ-9B Protector can remain airborne for over 40 hours in a clean configuration.

36. Defence Equipment and Support, '£100m Boost for Cutting-Edge Protector Aircraft', 11 September 2019, <<https://des.mod.uk/100m-protector-aircraft/>>, accessed 19 May 2020.

37. General Frank Gorenc, Commander US Air Forces Europe and Africa, speech given at the Joint Air Power Competence Centre Conference, Essen, November 2015.

situational awareness, with the option of precision strikes as needed. However, they have more restrictive weather condition tolerances than fast jets, are vulnerable to modern electronic warfare attacks against the satellite communication links used to remotely operate them, and are physically vulnerable to attack by any hostile air- or ground-based assets in range. As such, they are fundamentally limited to use in permissive airspace and are not suitable for high-intensity conflict scenarios. A notable potential exception would be if some of the RAF's Protector fleet, which is intended to comprise 16 airframes at the time of writing, were equipped for cooperation with the P-8 maritime patrol aircraft fleet in conducting anti-submarine warfare patrols against Russian assets in the North Sea and North Atlantic areas.³⁸ In that role, they could contribute to NATO high-intensity warfighting capabilities without having to operate prohibitively close to ground-based air defences and interceptors.

In summary, the RAF and Fleet Air Arm can deploy a remarkably broad spectrum of combat air capabilities for a medium power with a defence budget the size of the UK's. This is first and foremost a result of longstanding government policies during recent decades to maintain the ability to make significant contributions to US-led coalition operations at reach while also contributing to national and NATO defence taskings in Europe. At the core of the UK's airpower is a medium-sized force of modern multirole fast jets in the shape of Typhoon FGR.4 and F-35B, which is supported by a diverse ISTAR force, and a large fixed-wing and rotary mobility force to support power projection. However, with the exception of the small joint RAF/RN F-35B fleet, none of these assets are designed to operate in airspace defended by modern integrated air defence systems (IADS).

38. Andrew Chuter, 'British Defence Ministry Reveals Why a Drone Program Now Costs \$427M Extra', *Defense News*, 24 January 2020, <<https://www.defensenews.com/unmanned/2020/01/24/british-defence-ministry-reveals-why-a-drone-program-now-costs-245m-extra/>>, accessed 19 May 2020; George Allison, 'RAF Considering Using Unmanned Aircraft to Complement P-8 Poseidon', *UK Defence Journal*, 6 October 2016, <<https://ukdefencejournal.org.uk/raf-considering-using-unmanned-aircraft-complement-p-8-poseidon/>>, accessed 6 July 2020.

II. The Tempest Programme

TEAM TEMPEST WAS launched as the central element of the Combat Air Strategy in 2018, and has been reported by many sources as a fast jet development programme with the simple aim of building a replacement for the Typhoon fleet, for when the latter is phased out of service in the late 2030s and early 2040s.³⁹ This is, in part, due to the decision by then Secretary of State for Defence Gavin Williamson to announce the launch of Team Tempest in front of a concept mock-up model fighter and refer to it as a ‘world beating fighter jet’.⁴⁰ However, Team Tempest is actually an entity ‘made up of a group of industry partners ... working with the RAF’s Rapid Capabilities Office and the Ministry of Defence to develop the technologies needed for the next generation of combat aircraft’.⁴¹

Italy, another Typhoon and F-35 operator, also officially joined the Tempest programme in 2019.⁴² Sweden has also signed a bilateral agreement with the UK to cooperate on future combat air work, although it has not joined Tempest as a partner at the time of writing.⁴³ The core intention at the heart of Team Tempest is to develop a so-called ‘system of systems’, which collectively will deliver capabilities sufficient to replace the Typhoon fleet of fast jets in 2040.⁴⁴ The ‘system of systems’ concept refers to an approach where the capability is delivered by multiple different platforms working closely together, which might include, but are not necessarily limited to,

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39. Peggy Hollinger, ‘Ambitious Tempest Fighter Jet Programme to Accelerate in 2020’, *Financial Times*, 31 December 2019.
 40. MoD, ‘Britain to Take Leading Role in Next-Generation Air Power, as Defence Secretary Launches Combat Air Strategy’, 16 July 2018, <<https://www.gov.uk/government/news/britain-to-take-leading-role-in-next-generation-air-power-as-defence-secretary-launches-combat-air-strategy>>, accessed 28 May 2020; Gavin Williamson, ‘Today it’s my pleasure to announce Britain’s next generation and world beating fighter jet Tempest at @FIAFarnborough as we launch our Combat Air Strategy – a £2bn investment in an industry that supports 18,000 direct jobs, 100,000 in supply chain & worth over £6bn to UK #FIA18’, Twitter post, 12.08pm, 16 July 2018, <<https://twitter.com/GavinWilliamson/status/1018814556834074624?s=20>>, accessed 28 May 2020.
 41. RAF, ‘Team Tempest’, <<https://www.raf.mod.uk/what-we-do/team-tempest/>>, accessed 28 May 2020. These industry partners include BAE Systems, Rolls Royce, Leonardo, MBDA and, more recently, General Electric UK, QinetiQ, Collins Aerospace, Thales, Martin-Baker, GKN and Bombardier.
 42. Helen Warrell and Sylvia Pfeifer, ‘Italy Joins Forces with UK in European Fighter Jet Race’, *Financial Times*, 11 September 2019.
 43. MoD and Penny Mordaunt, ‘UK and Sweden Partner on Future Combat Air’, 19 July 2019, <<https://www.gov.uk/government/news/uk-and-sweden-partner-on-future-combat-air>>, accessed 26 June 2020.
 44. Unanimously agreed in closed roundtable sessions on future combat air choices at RUSI, London, 24 September 2019 and 20 January 2020.

piloted combat aircraft, UCAVs, swarming and standoff munitions, and offboard sensors. The aim is to avoid the inescapable trend in previous generations of combat aircraft – where rising demands for lethality and survivability constantly push unit costs and development timescales higher, resulting in ever-smaller fleet sizes.⁴⁵

The ‘system of systems’ approach aims to avoid the need to produce a single platform able to meet all lethality and survivability requirements organically. New industrial and programmatic approaches are also being undertaken to try to allow Tempest to break from previous development paradigm restrictions. These include developing major technology components – such as sensors, weapons, and novel propulsion and datalink technologies – which will be needed for Tempest on Typhoon during the 2020s. This approach aims to both enhance Typhoon capabilities and de-risk the core Tempest technologies early on.⁴⁶

What is not yet clear is whether the Tempest programme will explicitly aim to develop a replacement type of piloted fast jet combat aircraft to replace Typhoon as part of that ‘system of systems’. While this remains an implicit assumption on the part of many players within Team Tempest and external commentators, down selection of options is not due until late 2020, and no firm decision on that question has been reached yet.⁴⁷ The competing Franco–German–Spanish FCAS programme has much more explicit aims to replace the countries’ Rafale and Eurofighter Typhoon aircraft in the late 2030s with a new piloted fighter, despite also pursuing a ‘system of systems’ approach.⁴⁸ This is partly a result of both France and Germany not purchasing the F-35, meaning that their air forces lack a VLO combat air capability able to sustainably operate in highly contested airspace for the foreseeable future. With more limited mobility and ISTAR fleets, both Germany and France also spend a greater proportion of their air force procurement budgets on combat air.⁴⁹

The decision of whether or not to develop a piloted or optionally piloted solution as part of Tempest will have critical implications for the nature, cost implications and minimum viable scale of the programme. This is because piloted aircraft carry requirements for operational conversion units for aircrew training, multiple frontline squadrons to manage work-up, deployment, rest and maintenance cycles, and commonality of airframes within a fleet to allow pilots trained on one aircraft to fly any other. The result is that three to four airframes are needed for each one sustainably available for combat operations at any given point.⁵⁰ Consequently, piloted fast

45. MoD, ‘Combat Air Strategy’, p. 16.

46. Discussions during closed roundtable sessions on future combat air choices at RUSI, London, 24 September 2019 and 20 January 2020.

47. *Ibid.*

48. Author interviews with Dassault and Airbus subject-matter experts, Paris, 19 June 2019.

49. For more detailed information, see Bronk, *The Future of NATO Airpower*, pp. 40–56.

50. For example, in February 2018, 92 of the RAF’s 140 Typhoons were in the forward fleet, with the other 48 undergoing deep maintenance, overhaul or upgrade work as part of the sustainment fleet. The 92 in the forward fleet included those being used by non-frontline units (29 Squadron, OCU and 41 Squadron, TES), with the remainder distributed among the frontline squadrons, at

jet fleets require a significant critical mass of aircraft to be viable, which means decade-plus production runs to spread acquisition costs out, all while maintaining a standard fixed airframe design. This is just as true for optionally piloted solutions, although they could be flown remotely or autonomously when beneficial.

The need to acquire several squadrons worth of aircraft for each squadron's worth of active frontline strength at any given time is a core driver of combat air costs. Another is the fact that a majority of the extremely expensive flight hours flown by fast jets worldwide are to develop and maintain aircrew skills and currency for different conditions and mission sets. The RAF, like most air forces, is exploring how much of live flight training can be replaced with simulated flying in a synthetic environment. However, many key pilot skills which require 'feel' – such as adverse weather operations and g-heavy⁵¹ manoeuvres – are certain to continue to require live flying for the foreseeable future.⁵² Together, these requirements mean that any piloted solution implies a much larger fleet of airframes for a given frontline strength, and those airframes will have to be flown a lot more than a pilotless solution with high levels of in-flight autonomy.

UCAVs are an emerging category of unmanned combat aircraft designed for operations in highly contested airspace, and as such, they feature weapons and sensor capabilities, VLO airframes and a minimal dependence during combat situations on datalinks which could be denied by hostile electronic warfare.⁵³ This makes them very different from the RPAS, such as the MQ-9 Reaper, which have become synonymous with counterinsurgency warfare in the Middle East. UCAVs are pre-programmed with a mission profile before takeoff, which they then carry out automatically, with operators having the ability to monitor, update and re-task the system in flight except when emission-control measures or hostile electronic warfare preclude the use of datalinks. BAE Systems has already designed, tested and proven Taranis, a stealthy UCAV technology demonstrator with high levels of in-flight automation, which finished an extended

various degrees of combat readiness depending on the workup, combat ready, rest and retraining cycle. As such, a sustainable combat-ready total for Typhoon would be around 40, with a surge capacity of around 80 for a short period during a major crisis. See MoD, Response to FOI Request, FOI2018/01586, 26 February 2018, <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/686541/2018-01586.pdf>, accessed 24 June 2020.

51. G-forces are a core part of fast jet flying as a result of differential acceleration during manoeuvres at high speeds, increasing the gravitational forces placed on both airframe and pilot. 1g is the force of gravity normally experienced standing still at ground level, while pilots experience up to 9g on a regular basis during fast jet sorties. Remaining conscious and combat effective under these g-loadings requires special equipment and training.
52. Author discussions with F-35 instructor pilots, RAF Marham, 10 January 2019.
53. For a detailed explanation of UCAV development in the US, see Tyler Rogoway, 'The Alarming Case of the USAF's Mysteriously Missing Unmanned Combat Air Vehicles', *The Warzone*, 9 June 2016. See also Bronk, *The Future of NATO Airpower*, pp. 34–37; Bronk, 'Modern Russian and Chinese Integrated Air Defence Systems'.

and highly successful test flight programme in 2015 with a total programme cost of under £200 million.⁵⁴

Without the need to establish an aircrew training pipeline, complete with operational conversion unit (OCU), or establish a sufficient number of squadrons to provide a given number at combat readiness within aircrew training, deployment and rest cycles, a UCAV fleet could theoretically be close to 100% frontline. That frontline fleet would, naturally, still be subject to availability constraints due to maintenance requirements, software complexity and the need to rotate some airframes for periodic overhaul and upgrades. However, a given number of combat-ready aircraft could theoretically be maintained with a much lower overall fleet size compared to piloted or optionally piloted fast jets.

The defence-industrial implications of placing a UCAV at the heart of Tempest would be significant. The lower production volumes and rates which make UCAVs attractive from a military capability standpoint also greatly reduce potential profits per customer for industry. Lower production rates and total fleet sizes would also support fewer jobs than a large piloted fighter programme. Furthermore, obviating the need for the majority of non-combat flying hours would greatly reduce the value of the support and maintenance contracts that currently form a large part of combat aircraft programme financial viability for many manufacturers.⁵⁵ On the other hand, the ability to regularly iterate and modify UCAV designs in small production batches (due to the lack of pilot commonality requirements) offers potentially greater intellectual property generation and expertise retention opportunities over time.

UCAVs offer a potentially disruptive leap in terms of cost and combat capability for air forces. However, they are likely to be judged suitable only for high-intensity, state-on-state conflicts due to serious concerns over how to ensure compliance with international humanitarian law (IHL) for weapons systems with high levels of in-flight autonomy, especially with regards to target discrimination in situations relying on contextual human judgement. ROE would be far less complex in high-intensity wars than in complex counterinsurgency conflicts. Put simply, SAM battery radars and fast jets are recognisable through their electronic signatures and behaviours in combat which are highly distinct from civilian entities, making target discrimination much simpler in state-on-state warfighting scenarios. The standoff ranges, threat levels and operational tempo likely to characterise high-intensity combat against a peer or near-peer threat would also leave piloted fast jets and UCAVs alike without the information or time required for complex assessments of collateral damage likely to be caused by each weapon release. As such, lethal decisions made by human pilots would also be based on the same limited sensor cues that would guide UCAV rules of engagement.

54. Ben Farmer, 'Taranis Stealth Drone May See Final Test Flights Later This Year', *The Telegraph*, 13 September 2015.

55. For example, the current 10-year support contract for the RAF's Typhoon fleet is worth £2.1 billion. See BAE Systems, '10 Year Arrangement to Support Royal Air Force Typhoon Fleet', 12 July 2016, <<https://www.baesystems.com/en/article/10-year-arrangement-to-support-royal-air-force-typhoon-fleet>>, accessed 24 June 2020.

Furthermore, due to the far greater stakes and likely casualty levels involved in such a scenario, the IHL requirement for proportionality would be much less restrictive as the military necessity would be greater in relation to a given level of potential collateral damage. A key question on political and ethical UCAV suitability, therefore, is the degree to which state-on-state, high-intensity warfighting is a key driver for Tempest and future combat air investment in general.

III. High-Intensity Warfighting or Not?

THE FIRST AND most important question, which will inform the UK's choices on future combat air, is one that the MoD cannot answer: is high-intensity warfighting in a NATO context, with Russia as the primary threat, a core driver for the armed forces? It is a political rather than a military question, and needs to be answered by the upcoming Integrated Review. The National Security Capability Review published in March 2018 explicitly lists the resurgence of state-based threats, and particularly Russia's territorial aggression in Ukraine – as well as the weapons-grade nerve agent attack in Salisbury and actions in Syria – as a core part of the national security context, and reaffirmed the UK's unconditional commitment to collective defence through NATO's Article 5 mechanism.⁵⁶

It also states that the Joint Force 'will be credible and capable of addressing state and non-state threats both alongside other nations and on our own'.⁵⁷ In other words, that the remit of defence writ large is to be credible and capable in both state-on-state warfighting and counterinsurgency operations at reach, if necessary without relying on allies. Put simply, this is not a credible ambition while spending 2% of GDP on defence, even before the economic effects from the coronavirus pandemic are factored in. While much state-on-state confrontation occurs below the threshold of actual warfighting, effective deterrence and signalling with military assets in that grey zone requires a credible capability to escalate should such signals fail. That implies a need to be able to fight under high-intensity conditions, at least in a limited geographical and temporal context.

Modern state-on-state warfighting credibility with forces the size of the UK's requires them to be carefully equipped, trained and organised according to a coherent doctrinal concept of operations. This is especially the case when considering that the primary state opponent that the armed forces have to deter by fielding credible capabilities, in the context of a conflict in Eastern Europe in defence of NATO allies, is Russia. The equipment and doctrine of the Russian armed forces emphasise short-duration, high-intensity operations by armour- and artillery-heavy ground forces conducted under the umbrella of a dense and highly capable IADS; all supported by large-scale electronic warfare, cyber and information operations.⁵⁸

56. HM Government, 'National Security Capability Review', 28 March 2018, pp. 6, 8.

57. *Ibid.*, p. 14.

58. For details on Russian armour and firepower, see Watling, 'The Future of Fires', pp. 1–20; Igor Sutyagin and Justin Bronk, *Russia's New Ground Forces: Capabilities, Limitations and Implications for International Security*, Whitehall Paper 89 (London: Taylor and Francis, 2017). For details on Russian IADS capabilities, see Bronk, 'Modern Russian and Chinese Integrated Air Defence Systems'.

Russia also fields a wide variety of long-range precision strike capabilities and an unmatched strategic and sub-strategic nuclear arsenal. In purchasing power parity-adjusted terms, Russia was estimated to have spent \$159 billion on defence in 2018 alone, as part of a sustained effort since 2011 to close the capability gap with NATO in terms of rapidly fieldable force ratios closer to its borders.⁵⁹

If the UK wishes to field operationally credible forces to retain its position as a key framework nation within NATO, then its armed forces will have to be optimised to counter Russian strengths and exploit weaknesses. An all-purpose force design will simply remain outgunned, outranged and operationally ineffective against Russia in a collective defence context, while still being inefficient and expensive for lower-intensity global operations against non-state opponents. Essentially, the UK government needs to choose whether to optimise the armed forces for high-intensity, state-on-state warfighting or for low-intensity conflict as part of global intervention and counterinsurgency operations in support of other allies. While a force configured for one will still have some utility in other contexts, the demands of modern warfighting mean it is not a role for spirited amateurs. Without a definitive answer to this question, it is difficult to see how the MoD can make major progress on improving efficiency by delivering a more coherent and useful joint force within the limited defence budget available.

For the purposes of future choices around combat air systems, the political decision (or lack thereof) around whether to plan for high-intensity conflict against peer states has important implications. In an Article 5 scenario in Eastern Europe, the UK and the Alliance as a whole would be highly reliant on the ability of air forces to rapidly degrade the Russian IADS and bring heavy firepower to bear against Russian ground forces. This is due to the fact that the latter have a major firepower and heavy armour advantage against the NATO ground force elements which could be rapidly deployed into theatre.⁶⁰ European NATO members, including the UK, are critically deficient in modern SEAD/DEAD capabilities, with the Alliance being almost completely reliant on US Air Force and US Navy assets for that mission.⁶¹ These would take time to arrive in theatre in sufficient numbers, and would also be in high demand in the Pacific in the likely context that potential conflict in Europe was coupled with the US being tied up with Chinese or North Korean aggression elsewhere.

If the UK wishes to provide a credible warfighting capability to fulfil a role as a core framework nation within NATO against Russian threats, then combat air policy decisions should focus on fielding credible SEAD/DEAD capabilities, which currently constitute the outstanding bottleneck capability for the Alliance. Other Alliance members, such as France, Italy, Germany and Spain, have large combat air fleets that could make major contributions

59. Richard Connolly, 'Russian Military Expenditure in Comparative Perspective: A Purchasing Power Parity Estimate', Occasional Paper, CNA, October 2019, p. 22.

60. Watling, 'The Future of Fires', pp. 43–49; Jack Watling and Justin Bronk, 'Strike: From Concept to Force', *RUSI Occasional Papers* (June 2019).

61. Mark Gunzinger et al., 'Towards a Tier One Royal Air Force', Center for Strategic and Budgetary Assessments, 2019, pp. ii–v.

to NATO warfighting credibility, but only in conjunction with a major SEAD/DEAD effort. Apart from the limited F-35 fleets, the vast majority of European combat aircraft are not survivable within the coverage of a non-degraded Russian IADS. With the F-35 and Typhoon fleets, the UK already has the essential building blocks for SEAD/DEAD, but would nonetheless have to divest from other capabilities to procure the necessary munitions stocks, enhance its penetrating ISTAR capabilities beyond the 48 F-35s so far committed to and conduct large-scale training exercises to build the necessary skillset.⁶² Without a firm political decision to prioritise NATO warfighting capabilities as a core defence task, the opportunity costs of such an approach have so far proved to be too high in spite of a clear requirement.

The alternative decision – to leave high-intensity warfighting capabilities in Europe more broadly to the rest of the NATO Alliance – would also have significant implications for the British Army and Royal Navy, but would not necessarily remove the requirement for SEAD/DEAD capabilities for the RAF. With the proliferation of modern Russian and Chinese air defence systems to Iran, Syria and many other countries well underway, SEAD is likely to be a theatre entry requirement for overseas interventions over the coming decade, as small countries increasingly field defences which were the preserve of major powers until recently.⁶³ Even at a relatively limited scale, modern SEAD/DEAD credibility requires large quantities of munitions, penetrating ISTAR capabilities and specialist training. Thus, a decision not to invest in these capabilities entails accepting that UK Combat Air will be a second-wave policy option even in lower-intensity conflicts. At best, policy options would be limited to standoff strikes against targets designated by others until other coalition members had conducted the required destruction of ground-based threats. Going forward, keeping pace with modern ground-based air defence threats in air force terms is a requirement if the UK wishes to have greater sovereign freedom of action globally, even if it does not wish to prioritise high-end deterrence within NATO.

A political decision to deprioritise high-intensity warfighting credibility against Russia in a NATO context would significantly reduce the requirements for standoff and air-to-air munitions stockpiles, fleet resilience against long-range precision strikes and truly cutting-edge penetrating ISTAR capabilities for the RAF. This could be interpreted as enabling a continuing focus on current and incoming fleets optimised for operations in permissive airspace, including the MQ-9B Protector fleet, big-wing ISR types and the large rotary and fixed-wing mobility fleets. Under such an interpretation, the future shape of UK airpower as a whole is dependent on political decisions around high-intensity warfighting in a NATO

62. For a more detailed analysis of the requirements to configure the RAF towards SEAD/DEAD, see Gunzinger et al., 'Towards a Tier One Royal Air Force'.

63. For example, see the individual system operator lists under Missile Threat, 'Russian Air and Missile Defense', Center for Strategic and International Studies Missile Defense Project, last updated 15 June 2018, <<https://missilethreat.csis.org/system/russian-air-defense/>>, accessed 19 May 2020. See also Carlo Kopp, 'Proliferation of Advanced Air Defence Systems', Air Power Australia, March 2010, <<https://www.ausairpower.net/SP/DT-SAM-Proliferation-March-2010.pdf>>, accessed 19 May 2020; Bronk, 'Modern Russian and Chinese Integrated Air Defence Systems', pp. 1, 29.

context. The absence of those decisions at the time of writing leaves those in charge of the ongoing Combat Air Strategy with a wide range of future whole-force structure ambiguity. However, in reality, even a decision to deprioritise Russian military threats in Eastern Europe would not alleviate the requirement for credible SEAD/DEAD capabilities if sovereign freedom of action is to be maintained against near-peer competitors over the coming decade and beyond.

IV. The Combat Air Strategy in Budgetary Context

WHEN IT WAS launched in 2018, the UK's Combat Air Strategy set out broad initial policy goals: to keep the F-35 and Typhoon fast jet fleets capable and relevant until at least 2040 to ensure UK freedom of action in military terms; to develop and procure a replacement capability for Typhoon with initial operating capability (IOC) in 2035; and to maintain a globally competitive domestic combat air industry.⁶⁴ The next key milestone, according to the pre-coronavirus schedule, is an announcement of 'early decisions for capability acquisition by the end of 2020 (covering the class of capability, partnering approach, cost and delivery schedule)', which is intended to allow the MoD to 'confirm final investment decisions by 2025 to ensure delivery of an Initial Operating Capability by 2035'.⁶⁵ In other words, the MoD had intended to define the main conceptual and financial outline of a programme to replace Typhoon by the end of this year. With the postponement of both the Integrated Review and Comprehensive Spending Review due to the pandemic, it remains to be seen whether this schedule would remain in place. Nonetheless, the core issues are relatively clear.

The approach, as outlined in the 2018 strategy, implies at least three parallel combat air development and acquisition efforts: Typhoon mid-life upgrade work to keep the core RAF fast jet fleet viable and combat-relevant until 2040; a continuing ambition to acquire 138 F-35s throughout the life of that programme;⁶⁶ and the development and acquisition of a next-generation combat air capability to replace Typhoon under Team Tempest. A fourth strand involves the replacement of the RAF's ISTAR-focused, armed MQ-9 Reapers with a larger fleet of 16 brand new MQ-9B Protector RPAS, estimated to cost £1.14 billion as of January 2020.⁶⁷ The £2 billion committed to the Future Combat Air System Technology Initiative in 2018 covers the initial phase of Tempest work, including the exploration of next-generation sensor, propulsion and weapons technology, digital design tools and conceptual development efforts.⁶⁸ However, the £2 billion will not come close to funding a full-scale development and fleet acquisition programme. In 2011, the National Audit Office estimated total development, production

64. MoD, 'Combat Air Strategy'.

65. *Ibid.*, p. 30.

66. Deputy Chief of Defence Staff, Air Marshal Richard Knighton, Oral Testimony to Public Accounts Committee, 28 May 2020, <<https://parliamentlive.tv/Event/Index/e72ffd5f-49dd-4243-bafe-934aa268c22b#player-tabs>>, accessed 28 May 2020.

67. Chuter, 'British Defence Ministry Reveals Why a Drone Program Now Costs \$427M Extra'.

68. House of Commons Library Debate Pack, 'Combat Air Strategy Progress and Next Steps', CBP-0154, 25 June 2019, <<http://researchbriefings.files.parliament.uk/documents/CDP-2019-0154/CDP-2019-0154.pdf>>, accessed 27 May 2020.

and upgrade costs for the RAF's Typhoon fleet at £22.95 billion in cash terms.⁶⁹ Adjusted for inflation, this comes to around £34 billion in 2020.⁷⁰ Assuming a similar cost for a full-scale piloted Tempest replacement programme is still, in many ways, an optimistic assumption since it relies on the programme costing the same or less than its predecessor in inflation-adjusted terms, which would be unprecedented for a modern fast jet programme.

Some potential funds might be drawn from the research and innovation fund and the Department for Business, Energy and Industrial Strategy, while some might be contributed by industry in the hopes of export success. Nonetheless, the likely more than £25 billion core funding for a full-scale Tempest development and acquisition effort would have to come from the Defence Equipment Programme, with a significant amount frontloaded in the mid- to late-2020s for development work. However, of the £18 billion committed to combat air over the 10-year Equipment Programme from 2019–29, 'about half is allocated to Lightning [F-35] procurement and support and the rest for Typhoon capability enhancements, unmanned air systems and military flying training'.⁷¹ It is important to note that the approximately £9 billion allocated to F-35 procurement and support out of the total £18 billion covers only 48 aircraft, and does not include funding for any future order batches after 2024.⁷² Furthermore, the Defence Equipment Plan was already facing cost overrun risks of up to £13 billion over the 2019–29 period, according to the National Audit Office, prior to the coronavirus pandemic.⁷³ It is clear that even viewed optimistically, on current trends, there will be no headroom in the MoD's budget for significant F-35 orders beyond the initial 48 during the 2020s, nor a new combat air development and acquisition effort as part of the Tempest programme at a scale remotely sufficient to replace Typhoon by a new generation of piloted aircraft by 2040. A decision to fund a full-scale Tempest development programme as part of a national industrial strategy to protect jobs and stimulate growth post-coronavirus might well make sense on the basis of national return on investment calculations, but would have to be funded from outside the MoD's core budget. From a defence perspective, one or more of the three (or four including Protector) combat air priorities identified in 2018 will have to be dramatically scaled back, or the budget significantly increased at the expense of other major defence – likely specifically RAF – capabilities.

The mismatch between policy ambition and budgetary reality here leaves no easy choices. Each of the pillars of the Combat Air Strategy plays an important role. Typhoon provides the backbone

69. National Audit Office, 'Ministry of Defence: Management of the Typhoon Project', HC 755, Session 2010–2011, 2 March 2011, p. 26.

70. This calculation takes National Audit Office report figures and 1998 as the median spend year across the programme, and then adjusts for inflation to current prices using HM Treasury, 'GDP Deflators at Market Prices, and Money GDP March 2020 (Quarterly National Accounts)', 8 April 2020, <<https://www.gov.uk/government/statistics/gdp-deflators-at-market-prices-and-money-gdp-march-2020-quarterly-national-accounts>>, accessed 24 June 2020.

71. Louisa Brooke-Holland, 'Prospects for Combat Air: What Follows Typhoon and Lightning?', House of Commons Library Briefing Paper, No. 8304, 15 May 2018, p. 4.

72. House of Commons Defence Committee, 'Unclear for Take-Off?', para. 6.

73. National Audit Office, 'The Equipment Plan 2019 to 2029'.

and essentially irreplaceable combat mass of the RAF at least until 2040. The F-35 is central to the carrier strike concept around which the entire Royal Navy has been configured, as well as representing the sole credible UK SEAD/DEAD and penetrating ISTAR capability against states with modern IADS. Tempest is the only way that the UK can retain a national combat aircraft design and manufacturing capability, and is currently the assumed source of a replacement capability for Typhoon by 2040. Protector is a way to ensure the RAF retains a long-endurance ISTAR and strike capability in permissive airspace, while also being considered for maritime surveillance and support roles alongside the P-8 fleet.⁷⁴

For the UK, these different programmes are also interdependent to a significant degree. For example, a reduction in Protector numbers would mean a greater demand for Typhoon sorties in permissive airspace for close air support, strike and tactical ISR missions, using up airframe fatigue life and making it more expensive and challenging to keep the Typhoon force as a whole viable until 2040 with the finite aircraft available. Defunding Typhoon upgrades, such as the ECRS Mk.2 radar, would greatly increase programmatic risk for Tempest by removing key technology building blocks, and would raise demand for F-35s for higher threat missions due to reduced Typhoon survivability and lethality. By the same token, cancellation or a significantly reduced level of ambition for Tempest could threaten various important mid-life upgrades for the Typhoon force, which are partly being funded on the grounds that new sensors, propulsion improvements and datalinks proven on Typhoon will then be incorporated into Tempest. It would also increase the need for large-scale F-35 orders beyond the current 48 to provide a de facto replacement for Typhoon in the absence of a Tempest-derived successor fleet. Without significant additional F-35 orders beyond the already funded 48 aircraft, there will be greater need for advanced upgrades to Typhoon to enhance its SEAD/DEAD contribution capabilities and survivability, as well as more operational pressure placed on the Typhoon force through the late 2020s and 2030s. A low F-35 order total would also increase pressure on the Tempest programme to start delivering a capable new combat air fleet with IOC by 2035 to ensure UK combat air strength does not drop dramatically when Typhoon retires around 2040.

One option might be to significantly increase the share of the £32.1 billion total Air Command Equipment Programme budget for 2019–29 which is allocated to combat air, at the expense of the mobility and ISTAR fleets and enablers more generally across the RAF. However, combat air remains a uniquely expensive business, so cuts across the rest of the Air Command portfolio to make all three main strategy pillars affordable would have to be drastic. A large-scale culling of non-penetrating mobility and ISTAR fleets and acquisition programmes in order to increase combat air funding over the next decade could make sense within the context of an Integrated Review which announced a specific focus on fielding credible high-intensity warfighting capabilities as a framework nation within NATO. In the context of deterring Russian aggression in Eastern Europe, or SEAD/DEAD operations against near-peer states, many existing ISTAR fleets would have to stand off outside their effective sensor range during the initial stages of combat

74. Stew Magnuson, 'News from DSEI: RAF Considering Maritime Version of Protector Drone', *National Defense*, 12 September 2019, <<https://www.nationaldefensemagazine.org/articles/2019/9/12/raf-considering-maritime-version-of-protector-drone>>, accessed 28 May 2020.

operations, rendering them less useful. However, the two largest ISTAR acquisition programmes – E-7 Wedgetail and P-8 Poseidon – are procuring types which would play important roles during a major war, so are unlikely to be tempting choices for cuts as part of such a strategy.⁷⁵

The large rotary- and fixed-wing mobility fleets were right-sized for supporting sustained expeditionary operations in Afghanistan and Iraq, resulting in the UK possessing the largest such fleets in Europe. However, they also lack first-line relevance to high-intensity combat operations, with the exception of the A-330 MRTT Voyager tanker fleet, which remains critical in almost all circumstances to support the fuel-thirsty fast jets from outside the ground-based threat range. There would be a plethora of extremely useful second-line logistics support missions which the rest of the mobility fleet could contribute to an Article 5 type conflict, but in a reality where the UK cannot afford to field a full range of capabilities and other European NATO members possess significant tactical mobility fleets, a warfighting-led force structure review might choose to cut some fleets to free up more funding for combat aircraft. This assumes, of course, that trading long-term equipment operating and sustainment costs against acquisition budgets was allowed in the unusual context of the Integrated Review.

Even if significantly increased funding for combat air were found, either by cuts elsewhere or by increasing defence expenditure as a whole, it remains difficult to see how the UK could afford both significant procurement of F-35s beyond the initial 48 and also a full-scale fighter-type Typhoon replacement effort under Team Tempest during the same period. A fleet of only 48 F-35Bs would be able to generate a very limited sustainable frontline strength due to the demands of maintenance and readiness cycles and maintaining some airframes in the US for training purposes. This represents a problematic bottleneck in terms of available sorties for the critical penetrating ISTAR, strike and SEAD/DEAD missions which the RAF, Royal Navy and British Army will all be heavily reliant on throughout the 2020s and the 2030s, if the UK is to have a state-on-state warfighting capability. A fleet of only 48 F-35s would also all but guarantee interservice tensions between the RAF and the Royal Navy over land-based versus carrier-strike deployment priorities for the limited airframes available. Ultimately, neither service would have their operational requirements for the aircraft's capabilities satisfactorily met. However, if Tempest does not produce a viable replacement capability, there is also no clear path to replacing the crucial combat mass provided by the Typhoon fleet as the latter ages out in the late 2030s. A failure of Tempest to generate significant airframe production contracts would also all but guarantee the demise of UK defence industry combat aircraft design and manufacturing capacity.

75. E-7 Wedgetail is being procured as the primary airborne early warning and battle management asset for the RAF, replacing the ageing E-3D Sentry fleet. Strike package coordination and airborne detection and early warning of incoming attacks would be critical in a peer conflict and can be conducted from outside the range of ground-based threats. The E-7 also has significant potential for use as an electronic warfare platform in support of the rest of the force, using its large AESA radar array. The P-8 Poseidon fulfils the critical fixed wing anti-submarine warfare mission set, which is central to the ongoing viability of the UK's submarine-based nuclear deterrent and carrier strike concept.

Conclusions

IF THE UK government decides that the armed forces must remain capable of credibly playing a framework nation role within alliances, and of conducting sovereign operations in a conflict against other modern states, then combat air as a whole must be capable of credible high-intensity warfighting (at least for limited periods of time within particular operational theatres). In the modern world, this requires credible SEAD/DEAD and penetrating ISTAR capabilities to provide situational awareness and targeting information for long-range precision fires, whether those fires are air-, maritime- or land-launched.

The alternative political choice – to reject a serious warfighting capability as too expensive and something to be left to allies – would pose a somewhat more uncomfortable problem for future defence planners. If high-intensity warfighting credibility is not the core driver of force design, then are fast jets even necessary for the 2030s and beyond? Why pay for the performance, agility and survivability of a fast jet, if the RAF and joint force are only to be resourced for operations in permissible or semi-permissible airspace? What implications does this have for the way other services are structured and equipped? What is the UK's future as a partner of choice for the US or a NATO framework nation, if high-intensity combat is perceived as being too expensive and difficult?

Assuming the government rejects these future military and defence-industrial policy implications and confirms a commitment to warfighting credibility, there are limited viable pathways to the required capabilities for future combat air policymakers. An ambition to sustain all current RAF fleets, and either purchase significant numbers of F-35 beyond the initial 48 or develop a piloted replacement fleet for Typhoon, is not matched by available funding. However, government policy seems to require both credible combat air (including modern SEAD/DEAD capabilities) and the maintenance of a capable national military aerospace defence-industrial sector. Any course will inevitably involve difficult trade-offs with major capability implications or a requirement for significantly increased defence spending.

The analysis in this paper is based on an assumption that the UK's combat air strategy must draw predominantly on core MoD funding for viability. It is intended to help policymakers chart a course towards operational coherence in the future force based on realistic funding levels and stated policy aspirations. However, it is important to acknowledge that national-level economic and industrial policy decision-makers may have different perspectives that fall outside the scope of this paper. The UK's military aerospace sector generates impressive rates of return on national investment in terms of tax revenue, employment, export sales and IP. Should the government decide that a piloted Tempest programme at scale was a useful outlet for large-scale stimulus funding as part of post-coronavirus recovery efforts, then the costs of a full-scale capability replacement for Typhoon by 2040 are within the means available to the Treasury. However, funding for such an effort would need to come from outside the core defence budget to avoid serious damage to

the already stretched ability of military combat air planners to meet operational and strategic requirements with available resources during the 2020s and 2030s.

Policy Recommendations

Assuming that warfighting capability remains important as a planning consideration, the path of least resistance would be to purchase as many of the original 138 F-35 ambition as the equipment plan can bear during the 2020s, if necessary at the expense of other priorities. The F-35 programme has been dogged by delays and cost increases throughout its life, and availability and operating costs continue to prove problematic for many users. Yet, it remains the most capable combat aircraft available to the UK for operations in heavily contested airspace during the 2020s. It will improve in service only as the software and supply chain mature. Higher defence spending would be welcome, but given this seems unlikely, additional F-35 orders would need to be at least partly funded by cuts to those mobility and non-penetrating ISTAR fleets which, in a high-intensity warfighting context, would be valuable but not vital. In other words, the RAF would have to be directed to specialise in operations within defended airspace at the expense of capacity across a myriad of less demanding but still very useful and more common mission sets. A switch to purchasing the cheaper, more capable but not carrier-capable F-35A CTOL variant for dedicated land-based RAF squadrons beyond the initial 48 joint RAF/RN F-35Bs could contribute to lowering the cost implications of significantly larger numbers of F-35s. One way to offset some of the costs implied could be early retirement of the less capable and reliable, and increasingly expensive, Tranche 1 Typhoons in the late 2020s as F-35As became available. However, if only small additional F-35 numbers were deemed possible, then the loss of fleet commonality would probably make this split-purchase option more expensive in the long run.

Either way, barring a massive increase in overall defence spending, significant F-35 purchases beyond 2024 remain financially incompatible with a full-scale piloted vehicle-centric Tempest programme to replace Typhoon, even if some additional combat air funding can be found. But the alternative is to accept extremely limited SEAD/DEAD and penetrating ISTAR capabilities throughout the 2020s and 2030s in the expectation that the UK and Italy can, through Tempest, develop something more capable than (or at least comparable to) whatever the F-35 has evolved into by 2040, and acquire it in large enough numbers to fully replace Typhoon's capabilities across its multirole mission set. Given the limited size and budget available to both countries, especially compared to the roughly \$71.9 billion of purely research, development, testing and evaluation costs for the F-35 programme as of December 2019,⁷⁶ that seems an optimistic assumption at best, even if significant comparative programme efficiencies are achieved.

A choice to explicitly designate Tempest as a UCAV programme, while purchasing as many F-35s as can be funded alongside it, offers one route towards breaking this deadlock. Without the huge complexity, fleet scale, training, testing and certification requirements implied by a piloted or optionally piloted core air vehicle, a UCAV-centric Tempest programme could generate a

76. US Congressional Research Service, 'F-35 Joint Strike Fighter (JSF) Program', updated 27 May 2020, p. 25, <<https://fas.org/sgp/crs/weapons/RL30563.pdf>>, accessed 6 July 2020.

meaningful frontline combat mass approaching that of the Typhoon force by 2040 while only actually delivering one-third to half the airframe numbers. Directed rather than remotely flown, and capable of high levels of in-flight autonomy for operations against high-end threats, the entire fleet could theoretically be part of the frontline at any given time. Furthermore, there would be nothing to stop a UCAV with the capability to accomplish high-intensity SEAD/DEAD, strike and/or penetrating ISTAR missions without real-time human oversight being operated with more robust human in-the-loop control in scenarios where high-end electronic warfare is not an issue. With no pilot training and currency flying hour requirements, a slowly growing and shadowy UCAV force would also be much cheaper to maintain combat-ready per airframe in service. The lack of regular peacetime UCAV visibility would also contribute to deterrence via capability ambiguity in the eyes of potentially hostile powers – an approach regularly used by Israel, Russia and China with their nuclear and higher-end conventional weapons programmes.

Team Tempest industrial partners would be able to generate intellectual property and sustain design, development and manufacturing expertise through iterative development of each batch of UCAVs as threats evolve and technology improves. The sensors, weapons, electronic warfare payloads and propulsion technologies required would generate work for defence primes and subcontractors, albeit at a reduced scale compared to a piloted programme, but more sustainably over time. These technologies could continue to be tested on Typhoon where appropriate, providing a route to both de-risking Tempest and enhancing Typhoon's combat capabilities for the remainder of its service life. Such an approach would require a different industrial model compared to the large-scale multi-decade fighter production and support cycles. However, it nonetheless offers an opportunity to generate highly efficient military capability and sustain a core of domestic industrial capacity and expertise which is otherwise likely to prove completely unaffordable in the long term. If the UK is committed to developing a warfighting capability from the Tempest programme while also maintaining a credible combat air mix at the core of the joint force between 2020 and 2040, then this UCAV and F-35 acquisition combination appears to be the most viable solution. Italy operates the same fast jet mix as the UK, and Sweden (which has a bilateral agreement to work with the UK on future combat air) is currently acquiring a brand new piloted Gripen E/F fleet which will serve for decades. As such, both have requirements that could be satisfied by a UCAV-centric programme to complement existing piloted assets. For the UK and Italy, once Typhoon reaches the end of its service life around 2040, the parts of its mission set which still require a human pilot in the aircraft could then be fulfilled by a sizeable F-35 fleet, with the Tempest UCAV supplanting the latter as the key penetrating ISTAR, strike and SEAD/DEAD asset in any peer or near-peer conflict.

Piloted aircraft such as Typhoon and F-35 will remain essential for the foreseeable future in specific roles such as air policing and quick reaction alert where human contextual awareness and judgement are critical, while RPAS, including Protector, will likely remain the tool of choice for permissive environments. In the context of regenerating a credible warfighting capability, there would be potential questions around whether Protector still represents value for money since it is not viable in contested airspace. Nonetheless, compared to much larger crewed ISTAR platforms – such as RC-135W, E-7 Wedgetail and Sentinel – it is significantly cheaper and provides a highly efficient way to buy out expensive fast jet capabilities in permissive

airspace while delivering unrivalled endurance on station. Thus, while there might be questions about the requirement for all 16 airframes, a retained Protector RPAS capability sufficient to generate two or three orbits is likely one of the most efficient ways for a slimmed down warfighting-focused UK combat air mix to retain a valuable contribution for lower-risk, higher-likelihood counterinsurgency-type coalitions.

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