

Next generation command and control

Wing Commander Ben Sharp



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The Freeman Air and Space Institute is an inter-disciplinary initiative of the School of Security Studies, King's College London. The Freeman Institute is dedicated to generating original knowledge and understanding of air and space issues. The Freeman Institute seeks to inform scholarly, policy and doctrinal debates in a rapidly evolving strategic environment characterised by transformative technological change which is increasing the complexity of the air and space domains.

The Freeman Institute places a priority on identifying, developing and cultivating air and space thinkers in academic and practical contexts, as well as informing, equipping and stimulating relevant air and space education provision at King's and beyond.

The Institute is named after Air Chief Marshal Sir Wilfrid Freeman (1888–1953), who was crucially influential in British air capability development in the late 1930s and during the Second World War, making an important contribution to the Allied victory. He played a central role in the development of successful aircraft including the Spitfire, Lancaster and Mosquito, and in planning the wartime aircraft economy – the largest state-sponsored industrial venture in British history.

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About the author

Wing Commander Ben Sharp is a RAF Engineer Officer whose career has focused on enabling command and control for British military operations, both in the UK and whilst deployed worldwide. An advocate for information-led decision making, he has led large teams of personnel and negotiated at an inter-governmental level to deliver information systems critical to supporting frontline personnel and theatre commanders alike. He will shortly (July 2019) graduate from the Defence Academy's Advanced Command and Staff Course and return to Headquarters Air Command to join the rapidly expanding team that is developing space capability for the RAF.

Abstract

Since the Royal Air Force was formed, command and control doctrine, capabilities and procedures have followed a steady path of development. Yet warfare is becoming more complex, given it is being fought in multiple operating domains across multiple locations against a range of adversaries simultaneously. Commanders have an ever-greater need to prioritize the availability of timely and accurate information so they can make effective decisions about the employment of their forces. This paper argues that as the Royal Air Force steps towards becoming a next generation air force, additional investment in its command and control capability would allow this already essential aspect of air and space power to become its most important role.

This paper results from the author receiving an invitation to consider and challenge current thinking around Royal Air Force Command and Control to stimulate debate on the subject. The paper seeks to hypothesise that the future core warfighting capability of the RAF should be command and control, upon which the other vital air power roles and functions will be based. The opinions expressed are the author's own and do not necessarily reflect the views of the Ministry of Defence, Royal Air Force or Defence Academy of the United Kingdom.

Introduction

In his speech to the 2018 Air Power Conference, the Chief of the Air Staff (CAS) suggested that the Royal Air Force (RAF) was yet to fully embrace the challenges of multi-domain operations and future command and control (C2).¹ He sought to address this with announcements that Number 11 Group would be re-formed as the centre of the RAF's operational activity, and that C2 would become the fifth fundamental role of UK air power. With 11 Group now established, UK Air and Space Power Doctrine under review and wider Defence also seeking to regain its Information Advantage, a 'one-year-later' reflection seems appropriate, to judge whether it is time for the RAF to embrace C2 not only as a fundamental, doctrinal role but as its main, battle-winning focus for future operations and capability development.

Command and control remain distinct functions. Command recognizes the authority of an individual to direct forces, control relates to the exercise of that authority to implement a commander's orders.² Their combination into generic 'C2' can mask their differences, not least the need to understand, coordinate and synchronize assets through control to ensure their contributions to tactical, operational and strategic commander's objectives are coherent. This paper shows that this was borne out as C2 systems were developed in the RAF's formative years and through World War Two, further refined during the 1991 Gulf War, and that C2 and its underpinning information requirement now sit at the heart of the challenge facing modern Western militaries. This is at a time when potential adversaries are seeking to expose and exploit weaknesses at the 'seams' of control between units, formations and forces. The RAF has begun to reconfigure by prioritising its information needs so that it can engage on a constant and global basis across the operational domains of maritime, land, air, space and cyber. Yet, the risk is ever-present that today's capability planners will favour new versions of yesterday's combat systems, potentially leaving tomorrow's warfighters ill-equipped. It will therefore be reiterated that a broader review of *how* armed forces operate using C2 structures and systems, not just what they operate with, must become a well-resourced and constant feature of military strategy reviews and capability portfolios. Given such investment, this will see C2 become the core warfighting capability that commanders must prioritize to achieve operational success.

A growing need for C2 investment

The RAF's C2 structure began to evolve as soon as the service formed in 1918 through necessity to command the forces that were assigned to it, merging the Royal Flying Corps (RFC) and Royal Naval Air Service into a single entity. The RAF's command structure, largely based upon that of the RFC, then implemented the functions of control that allowed air power to make a significant contribution in the final months of World War One and to demonstrate the continued utility of an independent air force into the 1920s.³ Air C2 arguably came of age during the Battle of Britain with the Dowding System, named for the Commander-in-Chief of Fighter Command from 1936 to 1940, which was the wartime apogee of the UK's air defence C2 development. Its evolution had begun under Admiral Percy Scott in 1915 to defend against attacks by enemy airships and, under his successor Major General EB Ashmore, expanded during 1917 in a bid to protect London from bombardment by German fixed-wing aircraft. By 1940, the system had become a highly sophisticated, multi-layered, multi-domain and integrated network of sensors, control nodes, communications links, fighter squadrons and anti-aircraft artillery to manage the chaotic actions of a determined enemy.⁴ The RAF thus derived a distinct advantage in the face of challenging odds and resultantly achieved one of its greatest battle victories. That said, the focussed development of C2 for homeland defence was not replicated for deployed operations and the lack of coordination between air and land forces in the subsequent Burma and Normandy campaigns contributed to tactical failures.⁵ Only after a deliberate investment in C2 was the potency of deployed air power maximized, providing an early lesson about the need to consider cross-cutting capabilities to integrate joint effects.⁶

The major developments in C2 during the Cold War period stemmed from the US Air Force's (USAF's) experience of air C2 during the Korean and Vietnam wars. This contributed to a significant evolution in the procedural aspects of planning and control, resulting in the adoption by NATO of the Air Tasking Order (ATO) process.⁷ The process was fully tested during the 1991 Gulf War, which saw air power used with overwhelming, devastating effect by the US-led coalition. The conflict also represented the coming of age for space power, with a strong demonstration of the space domain's ability to substantially increase the lethality of all the other combat arms.⁸ There were some C2 challenges, especially resulting from the employment of air assets from a broad range of nations which highlighted issues with the interoperability of communications systems and the integration of tactics and procedures.⁹ Despite this, the unity of control of air operations that was achieved, if not unity of command of the air forces, emphasized the effectiveness of the ATO process.¹⁰ The ATO would become the cornerstone of the "centralized command, decentralized execution" concept that is now regarded as the only feasible means of controlling large-scale air campaigns, but which seems increasingly dated when one considers the steady drumbeat of the 72-hour cycle.¹¹ That is not to suggest air power has become inherently inflexible; the apportionment of assets within ATOs continues to allow highly responsive effects to be delivered from the air. However, the increasing complexity of combat operations, the need to anticipate the loss of information feeds and the associated requirement to simultaneously integrate effects in multiple domains through an ATO-type process is causing militaries worldwide to recognize that a renewed investment in C2 is urgently required.

As debate rages within Western forces over the future of C2, notably in discussions relating to 'multi-domain operations' and 'multi-domain C2', significant investment in C2 and information centric capabilities has been underway by potential adversaries for well over a decade.¹² Since at least 2004, China has recognized the significant operational benefit of diminishing its enemy's ability to fight in the way they have trained by degrading access to information sources and slowing down its enemy's observe-orientate-decide-act (OODA) loop.¹³ Equally, China's 2006 Defence White Paper set out the explicit intent to build 'informationized' forces capable of succeeding in modern, information-centric warfare as the central tenet of the People's Liberation Army's modernization.¹⁴ While China's military evolution appears focussed on non-expeditionary, defensive operations, for now, the accounts of China's development of information capabilities, artificial intelligence systems and a robust, protected C2 infrastructure should serve to focus Western minds on the need for similar investment.

Making information the lifeblood of the RAF

The RAF is already responding, having set itself a long term challenge to ensure its ability to deliver decisive air power effect and having been afforded the opportunity by the 2015 Strategic Defence and Security Review (SDSR) to grow for the first time in decades. In its 2017 Strategy, the RAF emphasized it can only meet its strategic objective of delivering a 'next generation air force capability' by becoming an "integrated air force that recognizes 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".¹⁶ Cynics could deride this intent, citing the previous examples of Network Enabled Capability and Network Centric Warfare that have only partly succeeded in creating a pervasive C2 and information architecture for the UK's armed forces.¹⁷ However there is now an increasing recognition within all levels of the RAF that the service can no longer afford to miss opportunities to exploit any and all information available in both the battlespace and the business-space. Gone are the days when engine, aircraft performance, logistics and financial data could be considered by-products of the activities through which they were produced. Instead, the aspiration should be that all data will be captured and capitalized on, turning it into information that is relevant, reliable and accurate enough to enhance decision making.

The Air Information Experimentation Lab (AIX) is a recent initiative launched under the oversight of the RAF Rapid Capabilities Office (RCO), specifically to advance the RAF's C2 and information capabilities. It came about in acknowledgment of the previous Secretary of State's direction to regain the 'Information Advantage' in response to the changing character of warfare and having observed the success of the Royal Navy's Programme Nelson and the British Army's Agile Warrior exercise series, which have also focused on advanced data analytics and artificial intelligence.¹⁸ As an example AIX activity, it is likely there will always be improvements that could be made in the exploitation of live surveillance data transmitted from different sensors monitoring an adversary's forces. The AIX would seek to analyse the data feeds, fuse them together in conjunction with other relevant information sources, and present them within ground or air-based decision nodes in real time, allowing commanders to adjust live mission objectives as required in response to the changing situation. The AIX is already allowing commanders to experiment with new methods of implementing C2 and is expected to work with the RCO to commission new information exploitation tools that will automate processes, bring personnel efficiencies and improve the pace and effectiveness of operational decision making.

Station-level information experimentation has also been encouraged, such as at RAF Leeming through its 'RAFX' activity. Exploiting RAF Leeming's role as host to several lodger units, station personnel have worked with their 90 Signals Unit colleagues to conduct rapid, 'spiral' development of procedures using the alpha, beta, live approach typically associated with the evolution of software packages. This has seen previously cumbersome paper-based processes become responsive digital systems that enhance operational output, better support users and save time and money. Similarly, the Joint Forward Air Control Training and Standardisation Unit, also at RAF Leeming, has been trialling a new digitally aided close air support system that, compared to legacy systems, is expected to improve the situational awareness of ground and air based warfighters across the UK's armed forces and increase their combat effectiveness. Such initiatives are encouraging a mindset shift amongst personnel: that change can occur swiftly given leadership, enthusiasm and a modest resource investment. They are also indicating that 'seedcorn' experiments at one RAF location can be effective concept demonstrators for expeditious, wider adoption given good communication to avoid stovepipes of activity.

While the above C2 and information enhancement activities might be considered 'low level', they positively highlight the breadth of activity underway within the RAF. They also indicate that relatively small initiatives, especially when combined with similar efforts across Defence, have the potential to deliver substantial, wider benefits, which is seeing air and space power developed and delivered as much on the ground in the UK as it is in the skies above the front line. This is not to diminish the ground-breaking work going on elsewhere. Number 56 Squadron's efforts to enhance C2, Intelligence, Surveillance and Reconnaissance capabilities and 11 Group's work to integrate cyber and space operational effects as routine activity alongside the delivery of air power are strong indications of positive forward progress.¹⁹ This is in addition to the recent investment announcement regarding the purchase of five E-7 Wedgetail airborne early warning and control aircraft, the forthcoming integration of both the Protector remotely piloted air system and the P-8 Poseidon maritime patrol aircraft, and the growth of the RAF's space cadre.²⁰ It is in this area that the RAF is seeking to exploit the success of the Carbonite-2 spacecraft concept demonstrator, to enhance the UK Space Operations Centre and to work with UK Space Agency colleagues, examining options to develop an assured, British position, navigation and timing capability.²¹

The significant information generation potential of these new capabilities highlights two attitudinal changes. Firstly, that interoperability of systems with partners inside Defence, across government and internationally is being seen as a priority. The opportunity to deepen the already close relationship with Australia, for instance, is apparent given Australia and the UK will both be operating the Wedgetail and Poseidon, as well as the F-35 Lightning, and with a new space cooperation agreement recently signed between the nations.²² Secondly, it is evident that C2 has become much more for the RAF than a focus on air operations centres and the implementation of air and space control using the threat of force. To fixate on these would be to fall into the trap of developing new approaches to old activities ('new old'). Yet there is no single, 'golden bullet' of technological capability that will permanently lift the fog of war or achieve the ubiquitous and seamless passage of information. Instead, a 'new new' approach is required to the entire military operating concept, that will enhance performance across the realms of operational and capability planning by focussing on improving data flows, enhancing information availability and enabling more effective C2.

Time to turbocharge RAF C2 development

In a 2016 paper, Lieutenant General David Deptula, a retired USAF officer with significant combat and C2 experience, sought to overhaul conventional thinking about air and space power.²³ Deptula outlined the concept of a 'combat cloud', shifting the focus from the delivery of precision effects towards "an operating paradigm where information, data management, connectivity and C2 are core mission priorities".²⁴ He envisaged a scenario in which to overcome a highly capable anti-access, area-denial system, the best possible, real-time information on the disposition of enemy forces and the detailed status of friendly forces would be required to enable effects to be brought to bear from a range of air, space, cyber, land and maritime units. Crucially, operational success would only be achieved by prioritising information flow around the battlespace, with the communications specialists telling the aircrew what flight profile to follow and commanders dynamically adjusting operational priorities in response to changing threat information. Deptula clarified this approach as moving beyond combined *arms* warfare to combined effects warfare, where the forces are "bound by a common appreciation for the value of sharing information as a critical element of national security operations".²⁵ The UK has a strong pedigree of delivering joint military outputs, particularly since the 1996 formation of the Permanent Joint Headquarters that has overseen the subsequent Iraq, Afghanistan and counter-Daesh campaigns. However, the UK's military appears to remain wedded to the notion of integrating planning at the operational level of command, with effects delivered at a tactical level on a component-by-component basis. Perhaps using the US Marine Corps as an example to learn from, any future C2 concept must surely embrace all five operational domains, driving the need for early conceptual engagement between the British armed forces to achieve outputs that are not just coherent but effective.

In many respects the UK is in a strong position to be able to rapidly advance the implementation of multi-domain C2. For instance, it has been suggested the US military often sees deconfliction as the limit of what is required to achieve joint effect, whereas the UK has been more adept at achieving the next level of tactical cooperation.²⁶ The intervention in Libya, Operation Ellamy, offers a positive example in the way effects were coordinated and delivered from each of the UK's armed forces. Equally, the Defence Operating Model, which sees the front line commands generate capability for a joint commander to employ, lends itself to stimulating integration on operations.²⁷ That said, the recent tendency has been towards reinforcing operational level working, with the establishment of the Standing Joint Force Headquarters, and even strategic level activity under the UK Fusion Doctrine.²⁸ There are also exceptions to the operating model, notably for homeland defence and resilience tasks where the front line commands control their own forces, albeit in line with strategic

direction and in coordination with their sister services. Nevertheless, it is at this tactical level where UK Defence has an excellent opportunity to develop a coherent multi-domain C2 capability, with the RAF in a good position to act as an initial hub given its announced lead for C2 of UK military space operations and the corporate expertise it has developed by having air personnel at the heart of Defence's cyber enterprise.²⁹ It is time, therefore, to follow CAS's 2018 example by making an open and frank assessment of the current maturity of C2 across the UK's military, initially on a domain-by-domain basis and then examining the joint force. This could be conducted by using the Multi-Domain C2 Maturity Model that RAF, USAF and French Air Force personnel cooperatively developed in early 2018, with the output's being to indicate how effective each force is across a range of measures, to set aspirational objectives for future development and to prioritize activity to reach those goals.³⁰ With an outline strategy in place and packages of work identified, it would then be possible to 'turbocharge' C2 development.

Returning to focus on the RAF, with the 'ends' underway of codifying C2 as the fifth fundamental role of UK air power and of delivering the objectives within 2017 RAF Strategy and the 'ways' established of generating multi-domain operations through 11 Group, the 'means' must now follow: providing a RAF C2 capability delivery programme, potentially as a headline activity within the expected 2020 SDSR. This would make investment across the Defence Lines of Development but would focus on doctrine and concepts, personnel and information to avoid the inclination by capability planners to focus on equipment acquisition.³¹ Intellectual investment should be the primary concern, following on from the RAF's Eagle Warrior and the USAF's Doolittle Series war games and joint C2 concept work, which have all highlighted the need to develop an agile, responsive approach to future C2.³² The defence scientific and technology community, professional military education programmes, academia and multinational agencies, such as NATO's Joint Air Power Competence Centre, would all be able to offer applicable cognitive insights if they continue to be suitably stimulated. Equally, innovative development work in the defence and wider industrial sector should be harnessed. Live exercises could also be adjusted to train personnel to operate under sub-optimal C2 conditions and in a disaggregated manner. Exercise scenarios that test personnel in a contested, degraded and operationally limited environment against live pan-domain effects that increase the fog of war should become routine and, as seen in the 2019 Red Flag exercise, may need to be prioritized over the need to maintain an otherwise full flying programme.³³ As a headmark aspiration, the National Air and Space Operations Centre at RAF High Wycombe could be set on a trajectory to evolve into the UK's first Multi Domain Operations Centre, given buy-in from the Royal Navy and British Army. By channelling the evident enthusiasm amongst the RAF's and Defence's senior leaders and the tenacity that is associated with proactive military personnel, leaps forward in C2 capability would be possible.

There would inevitably be challenges in generating a C2 capability delivery programme. Funding would have to be prioritized above competing demands for other military capabilities, at a time when the pressure on the Defence budget continues make headline news.³⁴ Personnel would have to be found to staff the programme team and, potentially, to bolster headquarters positions, in the context of a current 5% shortfall of RAF trained personnel.³⁵ Objective measures of effectiveness for C2 enhancements would have to be developed, lest the financial scrutineers legitimately enquire as to what, rhetorically, a '20% improvement in C2' would *actually* provide. Implementing the 'combat cloud' would come with hurdles such as technical interoperability, information security and the potential for senior commanders at the edge of the all-informed battlespace to use their 'long screwdrivers' to reach across and tweak well thought through plans.³⁶

Perhaps most significantly, current operational thinking and practises would be challenged and the frictions associated with implementing change to organizational behaviours and culture would emerge.³⁷ While the challenges would be numerous, unless work to develop C2 is accelerated by today's military personnel, making the required changes for the next generation to adopt, the adaptability needed to handle the uncertainty of tomorrow's conflicts will stretch away from us.³⁸ Strong leadership, consideration of the required developments as a change programme and the prioritization of the core mission priorities of maintaining effective C2, connectivity and information would allow the RAF, and UK Defence, to maintain and rapidly advance its decision making ability and operational edge.

Conclusion

It is excellent news that C2 is being written about in academic circles, widely debated, discussed at conferences, exercised and developed. It is also refreshing that the discourse is not limited to an evaluation of the practical implementation of commanding fielded forces and controlling their actions within the battlespace. Instead, a substantial and fundamental review is underway of what effective C2 in future conflicts needs to look like to ensure the RAF's continued operational success. This paper has briefly reviewed how the RAF's C2 structure developed and came of age during World War Two and was refined during subsequent campaigns, notably the 1991 Gulf War. It highlighted the pressing need for new investment given the advances being made by potential adversaries to develop information-centric warfare practices that will seek to expose and weaken the cracks in Western C2 systems. The steps being taken by the RAF to make information its lifeblood were outlined, which is seeing areas of low-level development gaining significant traction in enabling more effective decision making. Equally, the RAF's headline capability announcements that will enhance C2 into the 2020s and beyond were touched on. With it noted that the ubiquitous availability of accurate, real-time information around the battlespace should be considered a core mission requirement, potential steps to 'turbocharge' C2 development were outlined. These include proposals to measure the Defence's current C2 maturity, establish a RAF C2 capability programme, continue prompting intellectual investment into the study of future C2 and challenge organizational resistance that may be encountered.

The RAF is at a point of inflection regarding its C2 capability. There is will and encouragement from its senior leaders, as well as positive change being engendered across the service. The re-establishment of 11 Group as the lead for RAF multi-domain operations is particularly welcome and the momentum of the initiatives under its oversight must be maintained. Yet, the introduction of a C2 capability programme would provide the extra investment that is essential to fully enabling CAS's vision of delivering a next generation air force. With this crucial step, C2 would not just become the fifth fundamental role of air power doctrine but the core warfighting capability of RAF air and space power around which the other roles are built.

Endnotes

All links accessible as at July 5, 2019.

- 1 Stephen Hillier, "Keynote," Speech to Air Power Conference, London, July 11, 2018. <https://www.raf.mod.uk/what-we-do/centre-for-air-and-space-power-studies/documents1/speeches-apc18-cas-keynote/>
- 2 Derived from the definitions in: DCDC, *UK Air and Space Power*, JDP 0-30, 2nd ed (Shrivenham: DCDC, 2017), 121. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/668710/doctrine_uk_air_space_power_jdp_0_30.pdf
- 3 Stuart Peach, "The Airmen's Dilemma: to Command or to Control?" in *Air Power 21: Challenges for the New Century*, ed. Peter Gray (London: The Stationery Office, 2000), 130.
- 4 Stephen Bungay, *The Most Dangerous Enemy: A History of the Battle of Britain* (London: Aurum Press, 2009), 62 & 71.
- 5 Peach, "The Airmen's Dilemma," 139.
- 6 Sebastian Ritchie, "Rising from the Ashes: Allied Air Power and Air Support for 14th Army in Burma, 1943-1945," *Air Power Review* 7, no.3 (Autumn 2004), 27. <https://www.raf.mod.uk/what-we-do/centre-for-air-and-space-power-studies/documents1/air-power-review-vol-7-no-3/>
- 7 Robert Winkler, "The Evolution of the Joint ATO Cycle" (MSc diss., US Joint Forces Staff College, 2008), 19. <https://apps.dtic.mil/dtic/tr/fulltext/u2/a451239.pdf>
- 8 Colin Gray, "The Influence of Space Power upon History," *Comparative Strategy* 15, no. 4 (1996), 301. doi: [10.1080/01495939608403082](https://doi.org/10.1080/01495939608403082)
- 9 US Department of Defense, *Gulf War Air Power Survey, Volume I: Planning and Command and Control* (Washington, DC: Department of Defense, 1993), 334-337. <http://media.defense.gov/2010/Sep/27/2001329802/-1/-1/0/AFD-100927-062.pdf>
- 10 James Winnefeld and Dana Johnson, "Unity of Control: Joint Air Operations in the Gulf," *Joint Force Quarterly* 1 (Summer 1993), 99. <https://www.globalsecurity.org/military/library/report/1993/jfq1201.pdf>
- 11 JDP 0-30, 42.
- 12 Tim Zadalis, "Multi-Domain Command and Control: Maintaining Our Asymmetric Advantage," *JAPCC Journal* 26 (Spring/Summer 2018), 10. https://www.japcc.org/wp-content/uploads/JAPCC_J26_screen.pdf
- 13 Dean Cheng, "Space and Information Warfare: A Key Battleground for Information Dominance," in *Outer Space; Earthly Escalation? Chinese Perspectives on Space Operations and Escalation*, ed. Nicholas Wright, 25-30 (Washington, DC: Dept of Defense, 2018), 26. <https://nsiteam.com/social/wp-content/uploads/2018/08/SMA-White-Paper-Chinese-Persepectives-on-Space-Aug-2018.pdf>
- 14 Andrew Erickson and Michael Chase, "Informatization and the Chinese People's Liberation Army Navy," in *The Chinese Navy: Expanding Capabilities, Evolving Roles*, ed. Phillip Saunders et al., 247-86 (Washington, DC: National Defense University, 2011), 249. http://www.andrewerickson.com/wp-content/uploads/2012/01/Erickson-Chase_PLAN-Informatization_NDU_2011.pdf
- 15 RAF, *Royal Air Force Strategy: Delivering a World-Class Air Force* (High Wycombe: RAF, 2017), 4. <https://www.raf.mod.uk/documents/PDF/Royal-Air-Force-Strategy/>
- 16 *RAF Strategy*, 23.
- 17 See, for example, Joint Services Publication 777, *Network Enabled Capability*, https://webarchive.nationalarchives.gov.uk/20121109143917/http://www.mod.uk/NR/rdonlyres/E1403E7F-96FA-4550-AE14-4C7FF610FE3E/0/nec_jsp777.pdf; House of Commons Defence Committee, Fifth Report of Session 2003-04, *Defence White Paper 2003*, <https://publications.parliament.uk/pa/cm200304/cmselect/cmdfence/465/465.pdf>
- 18 MOD, *Mobilising, Modernising & Transforming Defence* (London: MOD, 2018), 16. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/765879/ModernisingDefenceProgramme_report_2018_FINAL.pdf
- 19 Number 56 Squadron is the RAF's Air C2ISR Test and Evaluation Squadron.
- 20 "Wedgetail to be RAF's New Early Warning Radar Aircraft," *RAF News*, March 22, 2019, <https://www.raf.mod.uk/news/articles/wedgetail-to-be-rafs-new-early-warning-radar-aircraft/>
- 21 Tim Robinson, "UK MOD goes more boldly into space," *Air and Space Power Association News*, May 25, 2018, <https://www.airpower.org.uk/uk-mod-goes-more-boldly-into-space/>
- 22 UK Space Agency, "Britain and Australia enter into space agreement," *UK Space Agency News*, October 3, 2018, <https://www.gov.uk/government/news/britain-and-australia-enter-into-space-agreement>
- 23 David Deptula, "Evolving Technologies and Warfare in the 21st Century: Introducing the 'Combat Cloud'," *Mitchell Institute Policy Papers*, vol. 4 (September 2016), 1. http://docs.wixstatic.com/ugd/a2dd91_73faf7274e9c4e4ca605004dc6628a88.pdf
- 24 *Ibid.*, 1.
- 25 *Ibid.*, 6.
- 26 Will Spears, "A Sailor's Take on Multi-Domain Operations," *War on the Rocks*, May 21, 2019, <https://warontherocks.com/2019/05/a-sailors-take-on-multi-domain-operations/>
- 27 MOD, *Defence Operating Model* (London: MOD, 2015), 4. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/484941/20151208HowDefenceWorksV4_2.pdf
- 28 William McKeran, "Fusion Doctrine: One Year On," *RUSI Commentary*, March 8, 2019, <https://rusi.org/commentary/fusion-doctrine-one-year>
- 29 RAF, "UK Defence Space Conference," *RAF News*, May 23, 2019, <https://www.raf.mod.uk/news/articles/uk-defence-space-conference/>
- 30 Developed under the oversight of the Trilateral Strategic Steering Group, as reported on by: William Perkins and Andrea Olivieri, "Is NATO Today Sufficiently 'Joint' to Begin Discussions Regarding Multi-Domain Command and Control?" *JAPCC Journal* 26 (Spring/Summer 2018), 16. https://www.japcc.org/wp-content/uploads/JAPCC_J26_screen.pdf
- 31 Defence Lines of Development, as per the Defence Operating Model: training, equipment, personnel, information, doctrine and concepts, organisation, infrastructure and logistics. Akin to NATO's DOTMLPF framework.
- 32 RAF, "Exercise Eagle Warrior," *RAF News*, January 8, 2018, <https://www.raf.mod.uk/news/articles/exercise-eagle-warrior/>
- 33 Air University, *Doolittle Series 18: Multi-Domain Operations*, LeMay Paper 3 (Maxwell AFB, AL: Air University Press, 2019). https://www.airuniversity.af.edu/Portals/10/AUPress/Papers/lp_0003_multi_domain_operations.pdf
- 34 DCDC, *Future Command and Control*, Joint Concept Note 2/17 (Shrivenham: DCDC, 2017). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/643245/concepts_uk_future_c2_jcn_2_17.pdf
- 33 James Kitfield, "Red Flag 2019: First Great Power Air War Test In Years," *Breaking Defense*, March 6, 2019, <https://breakingdefense.com/2019/03/red-flag-2019-first-great-power-air-war-test-in-years/>
- 34 David Bond and Sylvia Pfeifer, "Nuclear submarine costs threaten to swamp MoD," *Financial Times*, April 3, 2019, <https://www.ft.com/content/1add9e6a-549c-11e9-a3db-1fe89bedc16e>

- 35 Noel Dempsey, *UK Defence Personnel Statistics*, Briefing Paper CBP7930 (London: House of Commons Library, 2019), 5. <http://researchbriefings.files.parliament.uk/documents/CBP-7930/CBP-7930.pdf>
- 36 Aaron Kiser et al., *The Combat Cloud: Enabling Multi-Domain Command and Control Across the Range of Military Operations*, Air Command and Staff College Research Report (Maxwell AFB, AL: Air University, 2017), 26-29. <https://apps.dtic.mil/dtic/tr/fulltext/u2/1042210.pdf>
- 37 More on this in: John Jupp ed., *Air Force Leadership: Changing Culture?* (Cranwell: RAF Leadership Centre, 2007).
- 38 DCDC, *Global Strategic Trends: The Future Starts Today*, 6th ed (Shrivenham: DCDC, 2018), 11. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/771309/Global_Strategic_Trends_-_The_Future_Starts_Today.pdf

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