Whitehall Report 1-16

Maximum Value from the F-35

Harnessing Transformational Fifth-Generation Capabilities for the UK Military

Justin Bronk

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Published in 2016 by the Royal United Services Institute for Defence and Security Studies.

Whitehall Report 1-16, February 2016. ISSN 1750-9432

Printed in the UK by Stephen Austin and Sons, Ltd.

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RUSI is a registered charity (No. 210639)

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Acknowledgements

I am very grateful to all those who helped in conducting the research and writing for this report. I am especially grateful to the individuals from the Royal Air Force, Royal Navy, US armed services and defence-industrial partners who gave up their time and helped to facilitate interviews and site visits with their respective organisations. I also wish to thank Elizabeth Quintana and Peter Roberts at RUSI for their assistance and support. Finally, I would like to thank Lockheed Martin UK for agreeing to sponsor this research project.

Note on Methodology

This paper draws on open-source desk research, informed by more than thirty unclassified interviews with serving and former officers in the RAF, Royal Navy, British Army, US Marine Corps, US Air Force and US Navy. Industry specialists involved in the F-35 programme from multiple companies were also interviewed.

All analysis, conclusions and opinions expressed are the author's own.

Acronyms and Abbreviations

AESA	Active electronically scanned array
ALIS	Autonomic Logistics Information System
AMRAAM	Advanced Medium-Range Air-to-Air Missile
AWACS	Airborne Warning and Control System
BACN	Battlefield Airborne Communications Node
CAOC	Combined Air Operation Centre
CAP	Combat air patrol
CNI	Communications, navigation and identification
CSG	Carrier strike group
DCGS	Distributed Common Ground System
EOTS	Electro-optical targeting system
FOC	Full operating capability
GBAD	Ground-based air defence
IOC	Initial operating capability
ISR	Intelligence, surveillance and reconnaissance
ISTAR	Intelligence, surveillance, target acquisition and reconnaissance
MADL	Multifunction Advanced Data Link
NATO	North Atlantic Treaty Organization
NIFC-CA	Naval Integrated Fire Control-Counter Air
PED	Processing, exploitation and dissemination
QEC	*Queen Elizabeth* class
RAAF	Royal Australian Air Force
RAF	Royal Air Force
SAR	Synthetic aperture radar
STOVL	Short take-off and vertical landing
UK	United Kingdom
US	United States
USMC	US Marine Corps
VLO	Very-low observable

Executive Summary

WHEN THE F-35B Lightning II enters service with the RAF and Royal Navy from 2018 it will represent a significant advance in the situational awareness of pilots and their ability to interpret commander's intent. It will reduce dependence on reach-back capability to a Combined Air Operation Centre and/or support from large, vulnerable intelligence, surveillance, target acquisition and reconnaissance (ISTAR) assets such as E-3D AWACS or Rivet Joint. This will significantly enhance operational flexibility and survivability in heavily defended airspace which will boost the UK government's options in certain crisis situations.

Within the scope of the initial two squadrons of F-35Bs that the UK has committed to purchase in the 2015 Strategic Defence and Security Review, the most effective use of the aircraft is likely to be as a survivable intelligence, surveillance and reconnaissance (ISR) enabler in defended airspace to enhance the lethality, flexibility and survivability of legacy platforms such as the Typhoon and the Type 45. Whilst the F-35 will have the inherent capability to perform such a role, the rest of the UK's armed forces need to be set up to take advantage of this. If seamless interoperability is reached, the F-35 will allow these legacy assets to operate against targets and in areas which otherwise would be too heavily defended – either by providing targeting data in real time for stand-off munitions or by supressing key defensive nodes to provide a window for the main force.

However, in its early software versions, the F-35 is unlikely to be able to covertly share such data via low-probability-of-intercept datalinks such as the Multifunction Advanced Data Link – with non-F-35 assets. In its current form, the superb situational-awareness picture generated and presented to the pilot is lost unless the pilot specifically choses to record certain data for bring-back. This bring-back capability is not only limited by internal-memory constraints (which can and will be overcome) but by the fact that it requires action by the pilot in each case to preserve data for later off-board analysis. Given that much of what the aircraft will collect automatically in terms of ISR and signals-intelligence data will not be directly relevant to the pilot's mission at a given time, much potentially useful information will be lost. Data transfer by traditional Link 16 to other assets risks seriously degrading the F-35's stealth in contested electromagnetic-spectrum environments.

Enhanced data-management and sharing architecture capabilities compared with early software versions of the F-35 itself are likely to be unlocked by the early 2020s due to the pressing requirements for interoperability across multiple assets in the future concepts of operations of multiple partner organisations in the programme. However, the rest of the UK armed forces stand to benefit greatly if they can be configured to receive, process and make use of the data the F-35 will be able to provide, in order to realise the full force-multiplier capabilities of the aircraft. This will likely be an expensive process given the number of platforms that will require upgrading and the £350-million cost of upgrading the communications and Tactical Information

Exchange Capability on the small front-line Tornado GR4 and Harrier GR9 fleets in 2008–09.[1] The US Battlefield Airborne Communications Node system which provided a theatre-wide datalink relay and translation capability in Afghanistan cost around $1 billion. This raises a question about the balance of investment. Given the almost unlimited scope of connecting the F-35 to every system in the battlespace, Joint Forces Command would need to prioritise connectivity and bandwidth upgrades for the platforms that stand to provide the greatest increase combat power and flexibility. Despite the cost, benefits to the wider force could be substantial – overcoming the shortcomings in cross-platform high-bandwidth network capabilities in all three services. The current equipment programme does not appear to provide for a coherent strategy to approach this requirement.

Investment in the F-35 and the Typhoon should not be seen as a binary choice for the foreseeable future. Each aircraft offer strengths to complement the other's particular capabilities. The combination of F-35 and Typhoon can be far more potent than a force composed entirely of either type in many operational scenarios. In this sense, the UK has an advantage amongst F-35 partner nations as it can complement the stealth strike fighter with the brute performance, reliability and load-carrying capabilities of the Typhoon.

For the Royal Navy, the F-35B in its early software configurations will provide a significant boost to carrier strike and fleet air-defence capabilities following traditional operational models. However, to take full advantage of the capabilities offered by the jet in the future, the *Queen Elizabeth*-class (QEC) carriers and escort groups will require bandwidth and data-processing upgrades and new concepts of operations similar to the US Navy's Naval Integrated Fire Control-Counter Air (NIFC-CA) concept. Such changes towards a network-centric, multiple-sensor, multiple-shooter concept of operations would not only enhance the fighting power of the various assets in the carrier battlegroup but also facilitate future interoperability with the US Navy and US Marine Corps (USMC).

The F-35's survivable ISTAR capabilities make it well suited to air support of ground forces in contested environments. However, its utility in this role will remain limited in this regard by the small strike payload it can carry internally. This limitation could be significantly overcome by ensuring full interoperability with the British Army's planned next-generation communications network (Morpheus) to enable other 'shooters' such as the Apache and the Multiple Launch Rocket System to take advantage of the F-35's target-detection and identification capabilities.

The F-35 represents a significant challenge and a significant opportunity in the realm of training and maintenance for the UK. On the one hand, operating the single-seat, stealthy jet effectively and training pilots with advanced and highly sensitive capabilities will require significant investment in next-generation synthetic training facilities and networks. On the other, these investments will enable the UK to train for complex, high-threat war-fighting situations affordably and regularly in a way that can currently only be done at great expense in the US. On the maintenance side of things, the Autonomic Logistics Information System (ALIS) should

1. RAF, RAF press release, 15 January 2008, <http://www.raf.mod.uk/news/index.cfm?storyid=7DA64610-1143-EC82-2ED84181AF18359D>, accessed 7 October 2015.

streamline procedures and reduce costs once mature. However, the bandwidth requirements of the system impose significant demands, especially at austere locations such as the QECs.

If the UK military modernises its cross-platform connectivity, data processing, exploitation and dissemination capabilities, and concepts of operations, the F-35 and the military instrument as a whole will be vastly more capable and efficient. If it does not, the UK will not only be wasting a significant part of the F-35's potential capabilities, but will risk degrading interoperability with the US and other partners who have progressed further in their thinking on information and network-centric warfare. The latter term is one which has been around for decades and has never delivered on its promises. With the F-35 entering service in the USMC and around the world soon after, it is becoming a reality.

Maximum Value from the F-35

AS THE MOST expensive military development and procurement programme in history, the US-led multinational F-35 Joint Strike Fighter project, now designated the Lightning II, has attracted a great deal of controversy and speculation since the development contract for the aircraft was signed in November 1996. The F-35 programme will consume a significant proportion of the £20.3 billion the UK is planning to spend on military air power over the next decade.[1] Whilst it is not yet clear exactly how much the F-35 Lightning II programme will cost the UK, the US Government Accountability Office expects the US armed services to spend $126.9 billion procuring and sustaining 973 F-35 aircraft between 2015 and 2025. This equates to a cost of $130.4 million (over £80 million) per aircraft to purchase and operate over a ten-year period.[2] The best publicly available cost estimate for the first major buy of fourteen aircraft for the UK was £2.5 billion in 2014.[3] Both the previous estimates include one-off infrastructure, maintenance and set-up costs. Given the resources involved, it is critical that the potentially transformational capabilities of the jet itself are understood by the whole of defence and that existing assets and structures are adapted to take maximum advantage of possibilities previously unavailable to the military instrument. It is important that the government and the wider defence community understand that simply viewing the Lightning II as another advanced jet – an 'F-16 with stealth' – misses the point of the system. A shift in mindset is required.

Critics of the F-35 programme point to the aircraft's considerable cost and the fact that compared with many competing platforms with more conventional design philosophies, the F-35 does not offer the same kinematic performance, damage resistance or payload in low-observable ('stealthy') configuration. The aircraft's proponents maintain that judging the F-35 by the same criteria as previous fighter designs misses the point entirely. This paper is not intended to provide an answer to these debates. The highly classified nature of the electronic warfare, sensor and networking capabilities at the heart of the F-35 means that any publicly available attempt to assess the pros and cons of the design as a weapons system cannot do it justice. Whilst the aerodynamic capabilities, programme difficulties and basic performance data are all in the public domain, the actual capabilities of the jet in the context in which it was designed to operate are highly classified and, therefore, can only be described in very broad terms.

There is, however, a need to stimulate and shape policy debates on how the F-35 will enable the UK military and especially what is required to fully leverage the aircraft's potential capabilities through integration with the whole force in the air, at sea, on land and in space. At present, there is little public or political debate in the UK on how to achieve its full potential as a force multiplier; rather, the focus has been on platform numbers. Under the current schedule

1. Ministry of Defence, 'UK Defence in Numbers', DDC00976 August 2015, p. 8.
2. US Government Accountability Office (GAO), 'F-35 Joint Strike Fighter: Assessment Needed to Address Affordability Challenges', GAO-15-364, April 2015, p. 15.
3. Mark Urban, 'UK to Spend £2.5bn on F-35 Fighters', *BBC News*, 11 February 2014.

announced in the 2015 SDSR, the UK will have taken delivery of forty-two F-35B short take-off and vertical landing (STOVL) aircraft by 2023.[4] Of these, it is intended that twenty-four will be available to deploy on the the two *Queen Elizabeth*-class (QEC) carriers, with the remainder allocated to the Operational Conversion Unit (OCU), training and maintenance. Three aircraft will remain in the US engaged in operational testing, resulting in enough aircraft in the UK to form two front-line squadrons. The UK government has further indicated that it will purchase the full 138 F-35 commitment made earlier in the programme, although timescale and version remain unspecified; it is likely that the remainder of the buy will be predominantly consist of the conventional take-off and landing F-35A variant, as used by the US Air Force.

Given the lack of combat mass until the late 2020s (at the earliest), the F-35 offers far more potential combat flexibility if it could also be employed as a critical force enabler, rather than only as the 'tip of the sword'. Top-up purchases remain a possibility given the open production line and slowly falling unit costs for all variants – a situation which is expected to continue well into the foreseeable future. For now, in light of the emerging threat environment and legacy force mix, this paper will explore how the F-35 based on the QEC and on land can best be utilised to enhance the UK's military options and responses to different potential threats.

The Current RAF and Royal Navy Concept of Operations for the F-35

There are currently two schools of tactical thought within the Lightning II community in the British military. The first sees the F-35 as an advanced aircraft which will be able to perform the traditional role of a tactical strike fighter more effectively than ever before.[5] This view is particularly strong in the Royal Navy and is in line with current US Marine Corps (USMC) doctrine for the F-35B.[6] It holds that with its unprecedented situational-awareness capabilities, the F-35 will be less reliant on traditional support enablers and direct links with intelligence reach-back and targeting facilities such as a Combined Air Operations Centre (CAOC).[7] The F-35's sensor suite will give its pilots a level of tactical situational awareness previously only possible though direct links to large, vulnerable support assets such as E-8C Joint Surveillance Target Attack Radar System, RC-135 Rivet Joint and E-3 AWACS. Therefore, the F-35 pilot – 'alone and unafraid' as part of a small formation in enemy territory – will be able to interpret and execute commander's intent with greater contextual and situational awareness than ever before. The sensor-fusion engine at the heart of the F-35's on-board computer suite provides analysis as well as fusion of inputs from all of the aircraft's sensors, before presenting a processed ground- and air-intelligence picture to the pilot. For example, the AN/APG-81 radar might detect and analyse the returns from a hostile aircraft. The fusion engine would then

4. HM Government, *National Security Strategy and Strategic Defence and Security Review 2015: A Secure and Prosperous United Kingdom*, Cm 9161 (London: The Stationery Office, November 2015).
5. Author interviews.
6. Author interview.
7. Intelligence reach-back is the capability to relay data collected by assets in a combat theatre back to centralised intelligence units at facilities which are often based in the home nation for processing and analysis.

cross-reference this with any infrared signature and passive emissions detected against a database of known threats before presenting the pilot with a threat-identification much more concrete than one which relies on a single sensor. The pilot is, therefore, able to interrogate the pre-processed data from multiple sensors to make extremely well-informed judgment calls. This will undoubtedly enhance the F-35's survivability and increase the British military's freedom of action in high-threat environments by reducing the dependence of strike and interdiction missions on maintaining communications with support assets and commanders. A flight of F-35s in hostile airspace, co-ordinating and updating their respective situational-awareness pictures in real time through the low-probability-of-intercept Multifunction Advanced Data Link (MADL), will, in theory, have a far greater situational awareness than a commander in a CAOC relying on inputs from various dedicated intelligence, surveillance and reconnaissance (ISR) assets which must maintain stand-off distance from hostile threats.[8]

The second school of thought, however, sees the F-35 as a combat-ISR asset first and a strike asset second. This is in line with the US Navy's projected concept of operations (ConOps) for the F-35C, which gives primacy to its 'ability to detect and fuse information from many sources, and link that fused picture to other CSG [carrier strike group] aircraft, ships and decision-makers.'[9] Given the incredibly detailed situational-awareness picture which the F-35, especially operating as a four-ship connected by MADL, can generate, many contend that the best use of those F-35s is to share that data in real time with all the other air, sea and land assets participating in the operation.[10] As will be detailed later in the paper, the F-35 offers the potential not only to share an ISR picture in real time with legacy assets, but also to dramatically increase their combat potential through data-sharing and network-enabled tactical interoperability.

An F-35 pilot cannot be expected to be aware of, let alone understand and interpret, the vast majority of this sort of signals-intelligence information which his or her aircraft collects automatically. At present, most sensor data gathered by each F-35 are fused, analysed, presented to the pilot and then disappear, unless the aircraft is operating in 'open transmit' mode using Link 16, which may be detectable and, therefore, compromise survivability in a high-threat environment. If the pilot has to choose which information to record, and when to record it, for bring-back – except when transmitting on Link 16 – potentially vital data are lost and a huge potential benefit of the F-35 to the whole force is wasted. The pilot can manually chose to record cockpit-display data, electro-optical targeting system (EOTS) images and synthetic-aperture radar (SAR) maps, but is limited by the small memory capacity of the current mission

8. Aaron Mehta, 'New Data Link Enables Stealthy Comms', Defense News, 14 July 2013, <http://www.defensenews.com/article/20130714/DEFFEAT01/307140011>, accessed 3 August 2015.
9. Mike Shoemaker, 'Admiral's View: The Case for Aircraft Carriers and Air Wings', DoD Buzz, 11 August 2015, <http://www.dodbuzz.com/2015/08/11/admirals-view-the-case-for-aircraft-carriers-and-air-wings/>, accessed 16 October 2015.
10. For example, Jeannie Hilger, vice president and general manager of Northrop Grumman's communications division, has stated that 'In buying F-35, nations are gaining an enabler in the battle space, an asset whose real potential lies in its ability to be a force multiplier to one's existing assets.' See Jeannie Hilger, 'Are We Ready for the F-35?', *Financial Times*/Northrop Grumman microsite, <http://northropgrumman.ft.com/#!/ready-for-f35>, accessed 1 September 2015.

data 'brick' which constitutes the data bring-back capability.[11] This limited memory capacity has already been recognised as an urgent problem and by the time the UK declares full operational capability (FOC) in 2023,[12] the memory constraints will have been significantly alleviated.[13]

However, the configuration of the F-35's sensor-fusion and information-management system architecture which requires the pilot to choose when to record sensor information for bring-back is potentially more difficult to fix. Much of the information an F-35 will collect during sorties will not be directly relevant to the mission at hand for the pilot. He is, therefore, likely to miss information which could be very useful to the overall campaign but would not be brought back for analysis without his noticing and making the judgment call to record it. Furthermore, the F-35 will have significant potential to intercept and interfere with hostile (and neutral) communications, networks and electromagnetic emissions. A great deal of use could be made at the command level of such information if it can be analysed through an apparatus such as the US Distributed Common Ground System (DCGS) – a network construct which feeds intelligence data to specialist intelligence units and agencies to generate usable information at the strategic and tactical levels for commanders and combatants alike.

There is no reason why the F-35 cannot be developed to overcome these software- and communications-configuration parameters in time. The communications, navigation and identification (CNI) system on an F-35 can manage twenty-seven different types of communications signal – referred to as waveforms – including the MADL.[14] There are, therefore, a host of potential channels through which the F-35 can transmit and receive data with other platforms other than Link 16 which remains the NATO standard for aircraft. Furthermore, whilst MADL is currently limited to line of sight (LoS) communications among up to four F-35s within a flight, it seems likely that operators will eventually develop this capability further.

Link 16 itself was originally designed for secure communications within flights of aircraft within LoS. It was eventually mounted on satellites and a host of potential relay platforms including high-altitude, long-endurance unmanned aerial vehicles (UAVs) such as the RQ-4 Global Hawk, allowing it to be used as a broader network enabler. MADL or another of the many waveforms that the F-35's CNI can manage will very likely be developed by the US in a similar way for its large fleet of very low observable (VLO) assets. Trials have already proven that Northrop Grumman's Battlefield Airborne Communications Node (BACN), mounted on either a modified Global Hawk, the EQ-4B 'Net Hawk' at high altitude or an E-11A, can 'translate' MADL data into Link 16 format and relay these to other aircraft.[15] The BACN itself is compact enough that it could potentially be fitted to a wide range of platforms to provide connectivity between myriad waveforms and platforms. Initial plans to fit MADL to the F-22 Raptor as part of the Increment

11. Unclassified Lightning II capability briefing given at RAF Marham, 4 August 2015.
12. Full operational capability (FOC) is when a system is delivered to a user and it has the ability to fully employ and maintain the system to meet an operational need.
13. Author interview.
14. Aaron Mehta, 'New Data Link Enables Stealthy Comms'.
15. General Norton Schwartz, US Air Force (USAF), quoted in John Reed, 'F-22 Won't Get F-35 Datalinks, Yet', DoD Buzz, 31 March 2011, <http://www.dodbuzz.com/2011/03/31/f-22s-wont-get-f-35-datalinksyet/>, accessed 3 September 2015.

3.2A/B upgrades and possibly to the B-2 Spirit were shelved in 2010 due to worries about the technological maturity of the system and budget constraints.[16] However, the fact that the MADL was even considered for the B-2 Spirit – a platform designed for operations deep inside hostile airspace at intercontinental ranges – suggests that Northrop Grumman and the US Air Force (USAF) believe the waveform has long-range communications potential for stealth-dependent assets.[17] For the UK, it is also significant that the primary US platform for the BACN as a relay, the E-11A, is based on the same Bombardier BD-700 jet as the RAF's Sentinel R1. This means that a UK Sentinel replacement using a similar airframe could easily incorporate a comparable capability to help provide beyond line of sight (BLoS) and multi-waveform communications links between the F-35 and legacy Link 16-capable assets.

There is a paradox in current British thinking around the ConOps, concept of employment and concept of use for the F-35. On the one hand, the model which emphasises the F-35's role in performing 'alone and unafraid' strike and interdiction missions within defended air space using self-contained ISR and situational awareness to allow the pilot to interpret commander's intent suits the aircraft's anticipated software configuration at initial operational capability (IOC) well, but may not represent an efficient use of the initially small numbers available as a force multiplier. On the other hand, the ISR-centric approach which sees small numbers of F-35s providing real time, high-grade ISR and situational awareness for the whole force and relying on legacy assets for the majority of kinetic effects would give the greatest benefit to UK combat power as a whole. However, it does not fit with the F-35's capabilities until the MADL and the aircraft's data-management systems are configured to share information with other assets whilst maintaining low-observability and pilot focus on his or her distinct mission. This network-enabled ISR role for the whole force is unlikely to be possible until at least FOC in 2023.[18] In the longer term, the jet itself will not be intrinsically limited to one ConOps or the other but the configuration of the rest of the UK armed forces will dictate its usefulness in the latter role.

One of the benefits of the international nature of the F-35 programme is that a large number of states will be developing tactics and working to resolve interoperability issues with the aircraft. Users such as Israel have more pressing operational requirements than the UK to use the aircraft in combat operations early on it its service life. Therefore, they are likely to prioritise overcoming early connectivity and network-architecture bugs, as well as developing new tactics to make the most of the F-35's novel capabilities. Whilst partner nations will not necessarily be sharing such progress with the UK directly, the collaborative nature of the programme, joint virtual training environments and the software-driven nature of many capabilities mean that software and operational fixes will be available for potential sharing through the Joint Programme Office and can be more easily incorporated into future fleet-wide updates. Furthermore, since the US Navy

16. GAO, 'Tactical Aircraft: F-22A Modernization Program Faces Cost, Technical, and Sustainment Risks', report to the Subcommittee on Defense, Committee on Appropriations, US Senate, GAO-12-447, May 2012, pp. 8–9.
17. Chuck Paone, 'Center Team Works to Connect New Fighters, Bomber', USAF, 9 April 2009, <http://www.af.mil/News/ArticleDisplay/tabid/223/Article/120680/center-team-works-to-connect-new-fighters-bomber.aspx>, accessed 29 October 2015.
18. Author interview.

in particular is already thinking in network-centric terms for its future F-35C operations, there will be strong pressure from that side of the US armed forces to push forward with opening up the F-35's information-sharing capabilities as soon as possible.

Creating a Next-Generation Air Environment for a Next-Generation Aircraft

The F-35 is already capable of sharing 'key targeting, surveillance and other data' with older fighters such as the F-16 or the Typhoon via Link 16.[19] However, Link 16 is limited in terms of bandwidth availability and also detectability by enemy forces. For platforms which rely on being hard to detect for survivability, like the F-35, it is not ideal to have to advertise one's position inside hostile airspace by broadcasting on Link 16. Therefore, the US uses the BACN to convert advanced low-probability-of-intercept waveforms such as the MADL in the F-35 and the F-22's 'Chameleon' into Link 16 format for transmission to non-stealthy assets.[20] The UK currently has no such capability.

The F-35's open software architecture, powerful sensors, unprecedented automatic data fusion and analysis capabilities, combined with its low-observability should, in time, unlock combat tactics and options previously impossible for combat aircraft. However, the UK needs to be aware that when the first Lightning II squadron declares IOC in 2018, the aircraft will be hampered by being unable to covertly share or offload most of the data it gathers and processes without special 'adaptors' such as the US BACN. Furthermore, the RAF and the UK military more widely do not have the equipment or processes in place, nor on order, to make use of the F-35's data-gathering and data-sharing potential even once a system capable of translating the MADL into other waveforms is procured.

Whilst many in specialist Lightning II and communications planning communities understand these issues, the RAF as a whole is still organised, operated and connected as a legacy air force. This is not simply a case of not yet having 'fifth-generation' stealth fighters in the UK's inventory, but rather that the RAF in particular is still thinking of platforms, rather than of information, as the most important component in mission planning. In other words, RAF operations are planned around individual aircraft capabilities, as opposed to *collective* capabilities, which synthesise the sensor, network and weapon availability of the whole force. The US is significantly ahead of the UK, not only in communications connectivity enablers such as the BACN and network-infrastructure capabilities to turn information into usable intelligence such as DCGS, but also in conceptual thinking. All air-power platforms currently under development for the USAF are required to be DCGS-compliant and -compatible, and, therefore, suited to information sharing by design.[21] The Royal Australian Air Force (RAAF) is arguably ahead of British military thinking with its Plan Jericho, albeit only in conceptual terms so far. This aims to provide a framework to

19. Colonel Albert De Smit, Royal Netherlands Air Force, quoted in Andrea Shalal, 'Tests Show F-35s Can Share Data with Older Aircraft', *Reuters*, 28 August 2015.
20. Amy Butler, '5th-to-4th Gen Fighter Comms Competition Eyed In Fiscal 2015', *Aviation Week*, 18 June 2014.
21. Author interview.

transform the RAAF into a next-generation organisation in which all assets are fully networked and operate as an information-centric, rather than platform-centric, force.[22]

By contrast, the Joint Data Network – which was, in effect, a programme to deploy aerial broadband networking capability within the RAF for the F-35 and other UK assets – was cancelled as a cost-saving initiative in 2011.[23] The costs for providing such capability are certainly significant: the US multi-platform BACN solution at sufficient scale to provide theatre-wide coverage in Afghanistan required an investment of around $1 billion.[24] Any British solution would undoubtedly be on a smaller scale and, therefore, cost less. However, whilst Operation *Agile Thunder* is being run by the UK to explore specifically F-35 connectivity with other assets, there currently appears to be no overall strategy in place to develop a network of networks to ensure different platforms can exchange data freely.[25] However, given the almost unlimited scope – and potential cost – of connecting the F-35 to every system in the battlespace, Joint Forces Command would need to prioritise connectivity and bandwidth upgrades for the platforms that stand to provide the greatest increase combat power and flexibility.

Similarly, the Royal Navy is focused on trying to get the *Queen Elizabeth* carriers and F-35s into service, promising that the combination will revolutionise the way in which the UK employs carrier strike, whilst being limited to an 8-megabit broadband capability on the QEC. Eight megabits is insufficient to fully utilise the capabilities of a single F-35, let alone to attempt to make best use of one or more squadrons and link them with the rest of the air/sea/land battlespace picture. In other words, not only will the F-35B have difficulty sharing all the ISR and situational awareness until late software blocks, but the UK military does not have the interconnectivity, network bandwidth or operating principles to make efficient use of that data even once that problem is fixed. The lack of a coherent strategy to address this issue is illustrated by the fact that the BLoS communications programmes in the RAF are currently run completely separately from the LoS programmes.[26] This does not bode well for attempts to integrate different waveforms and combine BLoS and LoS communications across separate platforms which is what is required to make the best use of F-35. The capability boost that the F-35 can impart to the UK military as a whole will be determined by whether the data gathered and processed by the jets can, firstly, be offloaded without compromising the aircraft's survivability in hostile airspace and, secondly,

22. Royal Australian Air Force (RAAF), 'Launch of Plan Jericho', news release, 23 February 2015, <https://www.airforce.gov.au/News/Launch-of-Plan-Jericho/?RAAF-paBYh8E6x2DLBAj9kH6nUO2uUSDU+dtp>, accessed 19 October 2015; RAAF, 'Plan Jericho', February 2015.
23. Author interview.
24. According to Northrop Grumman, 'The US has invested significantly in [BACN]. Providing full, 24/7 coverage in a theatre as challenging as Afghanistan has necessitated the provision of a number of dedicated air platforms and investment of around $1Bn. BACN-type capability could, however, be provided in a variety of packages for the UK. The family of potential solutions ranges from fast-jet mounted wing-pods, through payloads carried by non-dedicated multi-mission aircraft to fully-equipped aircraft dedicated to the BACN mission. Clearly the costs to the UK, or another Allied nation, would depend on the scale, scope and capability of the proposed solution.' Author e-mail correspondence with Northrop Grumman, 8 October 2015.
25. Author interview.
26. *Ibid.*

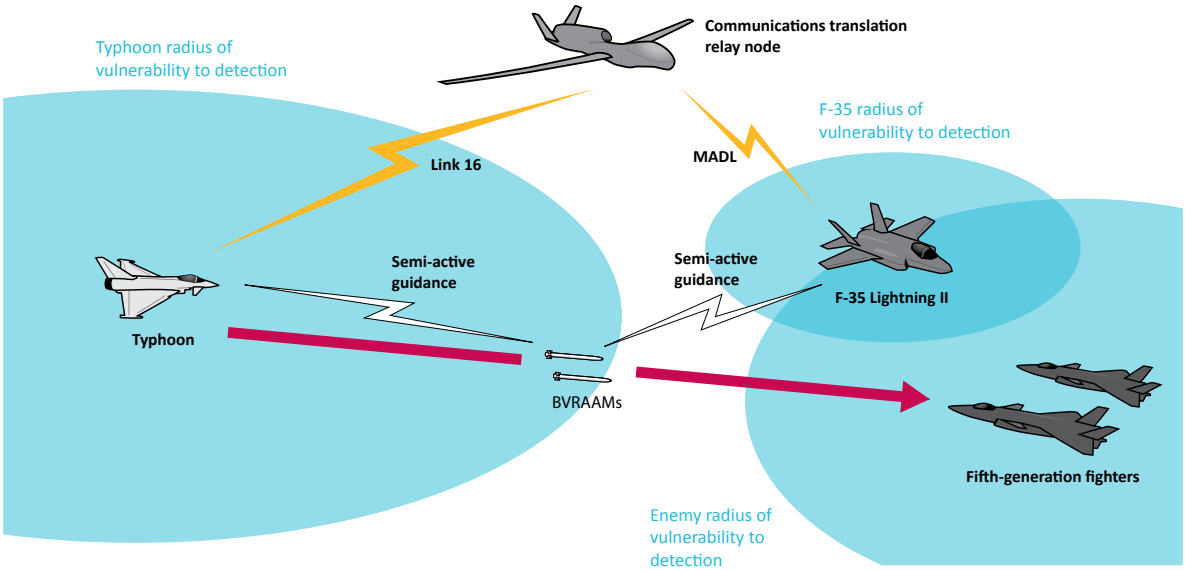
be efficiently utilised to enhance the situational awareness and combat power of non-stealthy assets in close to real time. At present, the second problem is likely to be the hardest to solve.[27]

The Air Environment

The US Red Flag exercises have consistently proven that the key determining factors in air-to-air combat are situational awareness, persistence in terms of fuel and missile stores, and pilot experience. Aircraft kinematic performance is a secondary aspect that only becomes critically important in a post-merge situation – a dogfight – where opposing aircraft are in visual contact with each other and are aggressively manoeuvring to bring the other into their sights. The way the RAF's Typhoon air-superiority fighters operate – with E-3 AWACS support and co-ordinating target information through Link 16 – is designed to ensure maximum situational awareness when approaching and operating in a given area of operations.[28] The large and powerful CAPTOR-series radars and large payload of the Advanced Medium-Range Air-to-Air Missile (AMRAAM), and soon-to-be-introduced Meteor beyond-visual-range air-to-air missiles at the heart of the Typhoon, are designed to detect and shoot enemy aircraft before opponents can employ their own missiles. Limiting factors are the detection range of the CAPTOR radar, especially against low-observable targets, and the requirement to launch against, and then maintain, the energy and positional advantage over an opposing fighter whilst simultaneously maintaining missile guidance in flight.

27. 'Many air forces are buying the F-35 without wiring it into rest of their armed forces … At the moment there is nothing at the other end – either on the fourth-generation fighters, headquarters or operating bases'. Greg Jones, Northrop Grumman, Director, Business Development for Airborne Networking, quoted in Hilger, 'Are We Ready for the F-35?'.
28. Justin Bronk, 'Maximising European Combat Air Power: Unlocking the Eurofighter's Full Potential', *RUSI Whitehall Report 1-15*, April 2015, p. 21.

Figure 1: Conceptual Representation of Future F-35/Typhoon Combat Integration in the Air-to-Air Context.



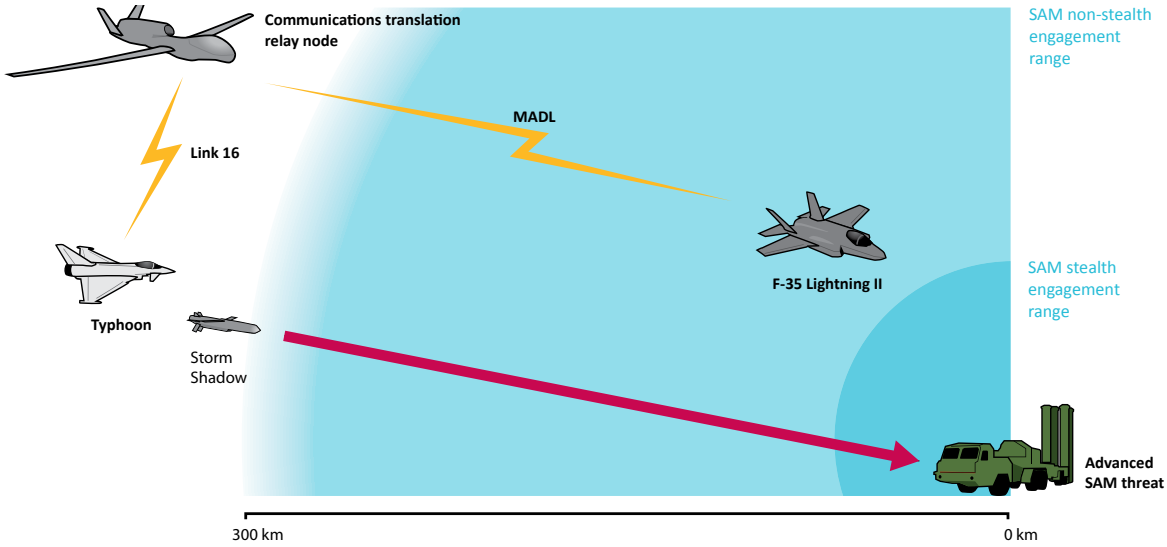
Note: This is a stylised representation of a hypothetical scenario in which the F-35 exploits its situational awareness and stealth design to passively detect future high-end air threats, relaying targeting information to the Typhoon which uses long range missiles to engage the targets and potentially act as a lure.

Small numbers of Lightning IIs operating alongside Typhoons in a combat situation involving an opponent operating aircraft such as Russia's Su-35S, China's J-15 or even stealthy J-20s could enable a whole host of novel potential tactics in the air-superiority task. With the powerful AN/APG-81 active electronically scanned array (AESA) radar and, perhaps more crucially, the passive AN/AAQ-37 Distributed Aperture System (DAS), the F-35 is the most capable flying sensor suite yet designed for detecting modern airborne threats whilst itself remaining discreet on the electromagnetic spectrum. Coupled with its VLO or 'stealth' design, the F-35 can get much closer to modern aerial (and ground-based) threats than more traditional fighter platforms like the Typhoon without being engaged. In this scenario, as in others, to simply think of the F-35 as a fighter is to waste the potential of the platform. If, instead, the F-35 could covertly transfer target data to Typhoons and, potentially, take over guidance of their AMRAAM/Meteor missiles once launched, the F-35 would greatly enhance the potential lethality and survivability of the Typhoon whilst the Typhoon would provide a significant firepower advantage to the F-35. The RAF air-capability development team already sees the future of both the Typhoon and the F-35 as symbiotic assets in high-threat environments. To that end, F-35 and Typhoon interoperability trials are scheduled to take place in the US in early 2016, both to evaluate the potential ways in which each aircraft can complement the other's combat potential and also to gain a better understanding of the present limitations and problems involved to inform future work.[29] The Typhoon and the F-35 should not be viewed as separate options for the RAF. Each type offers

29. Author interview.

strengths where the other is weak and if properly integrated, the combination offers significantly greater combat potential than the sum of its parts.

Figure 2: Conceptual Representation of Future F-35/Typhoon Combat Integration in the Suppression of Enemy Air Defence Context.



Note: This is a stylised representation of a hypothetical scenario in which the F-35's stealth and sensors allow it to get close enough to a high-end SAM threat to provide Typhoon with target data in real time for stand-off munitions (in this case Storm Shadow).

The US Navy is developing an operating concept known as the Naval Integrated Fire Control-Counter Air (NIFC-CA) which is at heart an expansion of the Aegis multiple-sensor/shooter-platform air-defence concept.[30] NIFC-CA is an attempt to link the sensor picture from multiple aerial assets such as the E-2D Hawkeye, P-8 Poseidon, MQ-4C Triton and F-35 with all the potential 'shooters' in range, especially AIM-120D-equipped F/A-18E/F Super Hornets and Aegis vessels with the SM-6 missile. The idea is that by sharing missile-guidance-grade data securely and in real time, the US Navy can project power well beyond the range of launch-platform sensors and from beyond the range at which enemy assets can easily threaten legacy assets such as F/A-18E/F Super Hornets and *Ticonderoga*-class cruisers. Such an operating concept offers huge potential gains in the combat potential of the UK military's existing assets both in the air and at sea, if implemented correctly with the F-35 as a central enabler. However, at present, the UK military as a whole is still thinking in terms of individual platform roles joined at the command and mission-planning level rather than an approach where each platform is itself simply a node on a network with sensor inputs and weapons capabilities linked across platforms as a core principle.

This sort of federated, real-time cross-platform and cross-service sensor data sharing is only one side of the coin. The other is how to make best use of all the ISR data which the F-35 will gather

30. United States Department of the Navy, 'Naval Aviation Vision 2014–2025, July 2013, p. 20.

either as a direct task or as a second-order effect of other missions as they are flown. Much of this may not be of instant tactical use but could yield important intelligence for the overall campaign. Data processing and analysis on a comparable scale is already being conducted to a certain extent by the USAF through the DCGS. The DCGS – officially the AN/GSQ-272 Sentinel – is a system which feeds ISR data in close to real time from compatible platforms across multiple US armed services to the 480th Intelligence, Surveillance and Reconnaissance Wing of the USAF. The information is then dynamically processed and exploited by multiple intelligence units based around the world, as well as security agencies, and then made available to various users in the field and in command structures. All new US aerial sensors are required to be DCGS compatible, including the F-35. With the UK already involved in the data-processing and intelligence analysis of the DCGS system, the introduction of the F-35 represents a potential opportunity to restructure the intelligence-gathering, exploitation and asset-tasking structures of the UK military along similar lines. The DCGS system also provides a significant step towards developing an operational concept of assets like aircraft and ships as nodes on a network and a more holistic method of using military forces – essential to obtain the maximum value from the F-35's unprecedented ISR-gathering and processing capabilities for the whole force.[31]

The usefulness of a significant portion of ISR data begins to degrade as soon as it is gathered due to its time-critical nature. It is, therefore, important for the UK to ensure it has aerial network nodes capable of offloading data from the F-35 and other assets and then either performing on-board analysis in the air or offloading it via high-bandwidth datalinks in real time. The French approach with their Rafale and Mirage 2000 fighters – which admittedly produce less data than the intrinsic ISR capabilities of the F-35 – is to use the Damocles targeting pod to offload ISR data to aerial tankers at a high, 15-megabit transfer rate, or to the *Charles de Gaulle* carrier at 8 megabits. Both the tankers and carrier have personnel on board to perform very quick processing, exploitation and dissemination (PED). This process is often fast enough to allow the original fighter which collected the ISR to be given a consequent strike tasking during the same flight.[32] Given the flexible nature of the RAF's own A-330 MRTT Voyager tanker transports, a similar capability would make great sense for the UK, especially if a BACN-type capability were to also be mounted in the aircraft to allow it to further act as a data-translation and relay node for multiple assets which might otherwise have to wait until they land to obtain PED for ISR gathered in flight.

Carrier-Enabled Power Projection

For the Royal Navy, the reconstitution of a credible carrier-strike capability is the primary concern surrounding the F-35 and the QEC carriers. Currently, the first deck flight trials by British F-35Bs will take place on the *Queen Elizabeth* in 2018, with a declaration of IOC for embarked combat operations expected in 2020. Having committed to the F-35B–QEC-carrier combination, the Royal Navy and the RAF need to ensure that this combination delivers a next-generation capability. Simply recreating a modern version of the operating models used for the

31. Author interview.
32. Author interviews.

late *Invincible*-class light carriers with their GR5/7/9 Harrier II and FA2 Sea Harriers would be a waste of the F-35B's potential. The F-35B is more than a stealthy Harrier.

On current plans, the Joint Lightning Force will have a maximum twenty-four F-35Bs embarked on a QEC carrier even in a time of crisis.[33] This translates to a potent force for fleet air defence, alongside the Type 45 destroyers, but to limited power projection ashore if required to operate as traditional fast jets tasked with fleet-protection combat air patrols (CAPs). Unlike the Sea Harriers famed for intercepting Argentine attacking aircraft within around 50 nm of the task force during the Falklands War, modern aerial threats are likely to be armed with anti-ship missiles with far greater stand-off range than the Exocet missiles and free-fall bombs. This means that F-35Bs involved in fleet air defence as part of a self-contained carrier battlegroup would have to operate further from the task force, which would reduce loiter times and increase demands for aircraft to maintain coverage 24/7 during periods of high threat. The US Navy already operates with engagement zones for carrier battlegroups of up to 500 nm, which is made possible by the larger number of aircraft – including E-2C/D Hawkeye AWACS – on board US nuclear carriers, and buddy refuelling.[34] Whilst the F-35B cannot offer the same range without air-to-air refuelling, there are several ways in which it could allow the QEC carriers to project a much more effective self-defence capability at ranges far greater than previous British carriers.

Whereas each CAP station around a task group would typically have involved at least a pair of fighters to ensure survivability and lethality, the F-35 could potentially fulfil a CAP role with only a single fighter on each station – although the directional nature of fighter radars in flight would limit coverage during certain portions of each orbit. However, despite the survivability of a low-observable design and superb situational awareness, a single F-35 would be limited by its internal missile capacity of four AIM-120C AMRAAMs.[35] This could be offset if the aircraft's sensor picture could be integrated in real time into those of the Type 45 destroyers which doctrinally provide fleet air defence. The Aster 30 missiles which, alongside the Aster 15, provide anti-aircraft and anti-missile punch for the Type 45 destroyers, have a range of up to 80 km. However, in many scenarios they could not be employed at such long range because of target-identification requirements. An F-35 on defensive CAP could greatly increase the usable engagement envelope of the Type 45 in the air-defence role by supplying it with both advanced early warning of incoming threats and, crucially, multiple sensor-enabled target-identification confirmation. This, however, requires the Type 45 and F-35 to be able to exchange data in real time, either directly or through a relay. The Crowsnest system, which comprises an early-warning radar system and communications suite fitted to Merlin helicopters for the Royal Navy, has been designed from the outset to be compatible with the F-35B and could act as a relay for its combined situational-awareness picture to the rest of the fleet.[36] Much of the ongoing *Agile*

33. However, the US Marine Corps currently envisages operating a squadron or more of its F-35Bs on the *Queen Elizabeth*-class carriers on a semi-regular basis from 2020 onwards.
34. Author interview.
35. The F-35B's internal weapons capacity for operations in low-observable configuration is two AIM-120C Advanced Medium-Range Air-to-Air Missiles and two 1000-lb-class Joint Direct Attack Munitions (JDAMs) for self-escorting strike missions or four AIM-120Cs for combat air patrols/ offensive counter-air operations.
36. Author interview.

Thunder project work being conducted with the Defence, Science and Technology Laboratory in the UK is currently looking specifically at Type 45–F-35B integration, including via Crowsnest. However, whilst the concept has been proven viable, significant hurdles remain.

The limited bandwidth of 8 megabits available on the QEC is a serious bottleneck in terms of the number of F-35s and other assets that the carrier can process and share data with at any given time. By way of contrast, the USS *America* amphibious-assault ship, built specifically to operate the USMCs F-35Bs, has been found to require 'vastly improved information and communications systems so [it] can receive and process unprecedented loads of data' despite already possessing a 32-megabit data bandwidth capacity at launch.[37] The US Navy's director of surface warfare is still concerned that even with upgraded systems, the volume of data generated by the F-35 and ALIS risks 'driving the ship to its knees'.[38] Clearly, the Royal Navy is going to have to grapple with a volume of data and demand for bandwidth which is beyond the current communications and networking equipment on the QEC. The UK has its own 'local' ALIS mainframe in the UK and terminals aboard the QEC carriers which can enable F-35B operations at sea without direct uplinks to the main servers at Fort Worth for several weeks at a time.[39] This will help to limit the demands made by ALIS for bandwidth during times of high strain, but it does not in itself solve the issue for the Royal Navy: the bandwidth available on the ship is nowhere near sufficient to make full use of the F-35B's potential capabilities.

However, it is worth remembering that the F-35B in its IOC software configuration is not optimised to share the vast majority of the information it gathers and presents to the pilot with other platforms. The Royal Navy is also much more concerned with achieving a 'night-one' strike and fleet air-defence platform to replace the Harrier GR9 and Sea Harrier FA2 than it is with making more ambitious use of the F-35 as a force multiplier and exquisite ISR sponge.[40] For the 'alone and unafraid' survivable strike and interdiction ConOps also being explored initially by the RAF, the lack of sufficient bandwidth for the QEC to receive, process and share the information the F-35B could provide is not a critical problem. There will be, however, compelling advantages if the Royal Navy appreciates and acts on the need to upgrade the capability of the QEC to act as a data relay for the F-35 and the various systems to which it can pass useful information. Recognising this need, and ensuring that the Type 45 destroyers and *Astute*-class submarines are network-enabled to a level comparable to the NIFC-CA ambitions of the US Navy, is also a precondition for maximising interoperability with the US at sea in the 2020s and beyond. There are great opportunities for such integration work. The F-35B itself should offer seamless network interoperability with the F-35B and C models operated by the US Navy and USMC without specific UK investment. The F-35B is also planned to be deployed as the leading survivable combat ISR platform within the US Navy's carrier air wings but only in relatively

37. Sandra I Erwin, 'Information Overload Could Complicate F-35 Deployments Aboard Ships', National Defense Magazine blog, 4 August 2015, <http://www.nationaldefensemagazine.org/blog/Lists/Posts/Post.aspx?ID=1794>, accessed 19 October 2015.
38. Rear Admiral Peter Fanta quoted in Erwin, 'Information Overload Could Complicate F-35 Deployments Abroad Ships'.
39. Author interview.
40. Author interviews.

limited numbers – around twenty-four per seventy-five fighter embarkation. Therefore, if the Royal Navy's ships can 'plug and play' with the NIFC-CA construct at sea, then a QEC carrier with a full UK F-35B complement of twenty-four embarked aircraft could double the stealth-strike and ISR-gathering potential of a US carrier battlegroup. The F-35 provides both a great opportunity and a significant driver to bring the Royal Navy's operating principles and network connectivity up to US Navy standards to allow true interoperability in the information-centric battlespace construct of NIFC-CA.

The Land Environment

Whilst the most immediately obvious areas where the F-35 can act as a force multiplier and enabler are in the air and maritime domains, there are significant capabilities within the land-force environment which the F-35 could improve in terms of flexibility and combat effectiveness. Just as in the air or at sea, situational awareness is a dominant factor in land warfare. With the capability to intercept all manner of electronic signals and communications, as well as high-definition SAR mapping and automatic vehicle-detection functions performed by the APG-81 and EOTS systems, the F-35's sensor suite is well suited to intelligence, surveillance, target acquisition and reconnaissance (ISTAR) over the battlefield – assuming it can share that data with other platforms. Whereas in Iraq and Afghanistan, large, expensive and vulnerable legacy ISTAR platforms such as the E-3 AWACS, RC-135W Rivet Joint and R1 Sentinel provided the majority of aerial intelligence for ground forces, alongside unmanned RQ-4 Global Hawk and RQ-9 Reaper UAVs, F-35s could provide similar situational awareness inside defended or contested airspace, or for deniable special-forces operations in hostile territory. The F-35's CNI system also offers potential covert and survivable communications relay capabilities for special-forces operators. To do all this effectively, however, the British Army's next-generation network and communications suite (Morpheus) will need to be able to directly interface with the F-35's MADL. There is still time for this requirement to be included, as Morpheus remains at a conceptual planning stage. Therefore, this issue should be a priority for Joint Forces Command as a key part of future joint-operations planning for the UK.

The F-35 is unlikely to be the most efficient platform to fulfil this niche in most situations due to its lack of unrefuelled endurance compared with UAVs such as the US RQ-170 and rumoured RQ-180 which were specifically designed for long-endurance missions to provide persistent ISR and communications in defended airspace. However, it offers self-defence and precision-strike capabilities which these platforms lack.

Other potential opportunities once the Block 5 and 6 software architectures are in service with the RAF and Royal Navy towards the late 2020s could include allowing the Apache to detect and engage targets at long range without using its Longbow radar actively and advertising its position in the electromagnetic spectrum. The Longbow radar, whilst excellent for rapid and wide-aperture target detection, emits an extremely obvious electromagnetic signature; the survivability of the Apache might be significantly increased in high-threat environments by being able to build a situational-awareness picture and engage targets without having to use

it in active mode.[41] Apache crews frequently exchanged data with fast jets during operations in Iraq and Afghanistan via Link 16 or laser communications.[42] The F-35 could take this sort of co-operation to the next stage, especially if the UK's Apache-replacement buy to deploy AH-64E standard aircraft makes such interoperability part of the requirements. In the direct close-air-support role, F-35s could supply precise GPS co-ordinates in real time for precision-guided Multiple Launch Rocket Systems or Excalibur 155-mm artillery shells to improve the accuracy and responsiveness of ground-based fires during high-intensity warfare or counter-insurgency operations.

Ground-based air defence (GBAD) is also a key area where land-based assets could benefit from significant increases in combat potential if operating in the same networks as F-35s. For GBAD systems, the engagement window – the time during which an incoming threat can be tracked and launched against successfully – is often the crucial limiting factor in threat-engagement scenarios. The F-35's ability to pick up hostile missile and artillery fire from great distances through the EOTS and the DAS could provide a significant capability boost to many systems such as Aster 30, SM-6, SM-3 and even C-RAM which are limited in terms of engagement envelopes by the radars by which they are fed. However, the requirement for persistent and broad coverage inherent in the GBAD mission suggests that whilst the F-35 could potentially boost the combat power of such systems if in range of threat launches, the limited number of aircraft available to the UK and multiple demands for their capabilities will prevent this role being actively pursued as a priority.

Training and Maintenance

A significant departure in the F-35 from all recent British fighter aircraft is the lack of a twin-seat training version. For every pilot, his first solo will be his first flight in the aircraft. Understandably, therefore, the synthetic training aspects of the programme have received a great deal of work and attention. The simulators which pilots train in prior to taking their first flights, and continue to train in extensively as standard procedure when assigned to the type, run on the same software as the real aircraft and have been designed to be as faithful as possible to the original. This is less of a departure for the UK fast-jet community than for some other partner nations, since the RAF has been actively pursuing a high ratio of synthetic training to live flying in the Typhoon force for many years. A 50/50 mix of synthetic to live flying is the current target for the RAF's Typhoon squadrons and will be the initial aim of 617 Squadron when it becomes the first UK-based Lightning II squadron at RAF Marham in 2018. Not only will this significantly reduce operating costs compared with traditional training and currency models dominated by live flying, but it also allows pilots to practice and gain experience in using capabilities such as Meteor and active electronic attack and jamming which are impossible to train 'live' in UK airspace due to range or security restrictions.

The F-35 represents a step change from Typhoon's synthetic training requirements since a wider variety of personnel beyond the pilots themselves will need to gain experience in operating

41. Author interview.
42. *Ibid.*

and supporting F-35 operations. Therefore, not only will simulators at multiple locations need to be securely linked over networks with sufficient bandwidth to handle the volume of data generated by the F-35's software, but mission command will have to be simulated with 'players' from CAOCs to forward air controllers and air-traffic controllers involved in large-scale synthetic scenarios from multiple locations in real time.[43]

The investment and planning challenges that this next-generation training infrastructure present are intimidating. Yet they also represent a huge opportunity for UK defence. If Lightning II can be harnessed as the stimulus to force through a much-needed large-scale investment in synthetic training networks and facilities in the UK, the result could transform the readiness and combat capability of UK airpower far beyond the F-35 itself. The DOTC(A) programme run as part of the Lightning project aims to provide a collective, distributed training environment, with linked simulators around the country, becoming operational in a phased approach from 2019. The capability to regularly simulate large-scale combat operations in high-threat environments with aircrew, mission planners, commanders and intelligence personnel taking part in real time from multiple sites across the UK, and potentially from abroad, could provide unprecedented benefits in terms of combat readiness, joint operations and the tactical flexibility gained from regular experimentation and practice in representative combat conditions.

In terms of live training in the air and for ground personnel, the F-35 offers both advantages and drawbacks compared with previous aircraft operated by the UK. On the one hand, the complexity and stealth coatings of the jet mean that maintenance is likely to be simultaneously more taxing and require an even higher standard of finish than on previous aircraft such as the Tornado, which do not rely on stealth for survivability. The automated ALIS system has been designed to counter this by moving the F-35 away from traditional preventative maintenance practices by constantly monitoring all the aircraft's systems and components in flight and on the ground to allow maintenance procedures or parts replacement to be performed only when required. ALIS should significantly reduce maintenance and operating costs when mature, but the system is still some way from final maturity and bugs remain.[44] However, Version 2.0.2 software which is expected in USAF service in 2016 is expected to solve many outstanding issues and ALIS, as a whole, is now a programme priority for the USAF and Lockheed Martin so it is reasonable to expect that by the time the UK declares IOC in 2018, the system will be significantly more mature.

The RAF already has substantial experience in operating maintenance procedures which involve a close partnership with industry due to the Tornado and Typhoon maintenance contracts with BAE Systems. Therefore, aside from the bandwidth and hardware-support infrastructure already discussed, the RAF is unlikely to require a major mindset shift to incorporate Lockheed Martin contracted maintenance arrangements based on ALIS for its F-35s. However, whilst the Royal Navy is already heavily reliant on contract-based maintenance structures on land and in port,

43. Author interviews.
44. Christopher Bogdan, Testimony to House of Representatives Subcommittee on Air and Land Forces, 21 October 2015, <http://www.c-span.org/video/?328865-1/hearing-f35-joint-strike-fighter&start=4230>, accessed 27 October 2015. The relevant section is from 01:10:30 to 01:12:21.

the number of contractors likely to be required to maintain ALIS and the F-35 at sea will need a new balance between military and civilian personnel whilst deployed. The maintainability of the F-35 will largely determine the cost and availability of flight hours on the limited number of platforms in the fleet; in turn, this determines how well the RAF and Royal Navy can train in the live environment. Whilst synthetic training is vital and a potentially highly potent tool to increase the capability and flexibility of the personnel who will fight with and around the jet in combat, real-life flying will still be essential to maintain currency for everything from multi-role operations to deck landings. The advanced flight-control computers on the F-35 make actual flying much easier than for previous generations of tactical fighters, but G-forces, weather and other dynamic, real-world factors must still be trained for regularly if combat proficiency is to be maintained.

A significant benefit of the F-35 for the UK in terms of training and readiness is the advanced flight-control software, coupled with the vertical-landing capabilities of the STOVL 'B' variant, which will mean that far less practice is required to maintain safe currency for complex and dangerous procedures such as deck landings on the QEC carriers in bad weather and at night. This will not only reduce cost and work-up timescales for deployments, but also allow pilots to concentrate on more combat-related proficiencies in the limited flight hours available to them each month. Furthermore, because all the sensor and targeting capabilities on the jet are self-contained rather than being mounted in external pods, pilots can train with them on any aircraft in the fleet. This is in contrast to the Tornado and the Typhoon which rely, to a large extent, on external pods such as Litening III and RAPTOR for multi-role capabilities, as well as existing in various hardware upgrade standards creating 'fleets within fleets'. There are seldom enough pods or 'diamond-standard' jets with the latest upgrades and equipment to train the whole front-line force and keep it current for the various roles required. Whilst the latest external pods in specialised roles, such as tactical reconnaissance, may be more advanced than some of the capabilities of the F-35, the latter's EOTS system, AESA radar and DAS components are all internal and mounted in every jet. This means that all pilots will be able to 'train as they will fight' with an aircraft which will rely predominantly on software upgrades rather than hardware and external equipment to increase its capabilities in future years.

Conclusion

Like any military aircraft, the capabilities available to the UK from the F-35 Lightning II when it enters front-line service in 2018 will be limited compared with its potential in the medium term. In its early software configurations, the F-35 will be best suited to a highly survivable strike role for use in defended airspace. However, software upgrades will form the bulk of maturation work and, therefore, additional capabilities should be added relatively quickly compared with previous platforms. In the 2020s, the F-35 has the potential to be a huge capability and flexibility enhancer for legacy platforms in all three domains because of its abilities in gathering, processing and sharing information. This is probably the most significant benefit that the aircraft can bring to the UK armed forces. In the 2030s and beyond, there will almost certainly be a plethora of operational uses for the F-35 which have not been conceived at this point. The combination of software-based upgrade pathways, open system architecture and operational

necessity suggests that Lightning II in British service will be put to even more imaginative uses than previous generations of platforms such as the Tornado which served in multiple roles far beyond their ConOps at IOC during their service lives. The fact that the F-35 will be operated by so many states, each with their own unique ConOps and requirements, should further boost tactical and conceptual innovation with the jet once it has entered service and fulfilled its initial requirements.

From the outset, the F-35 will give British pilots a level of situational awareness, independent of supporting ISTAR assets, greater than that which has been possible with any other tactical fighter. The question is to what extent that situational-awareness picture which is generated automatically and presented to the F-35 pilot can be successfully shared and utilised by legacy assets in the air, at sea and on land. Link 16 already allows the F-35 to share data with legacy platforms but with significant bandwidth issues and survivability degradation in contested environments. Given the small numbers of F-35B aircraft which will be available to the UK armed forces before the late 2020s, their combat potential and value for money will depend to a large extent on how great a force multiplier they can be for legacy assets.[45] By the time the UK expects to declare FOC for its F-35B fleet in 2023, initial problems with weapons integration, early-block software limitations and network data-sharing architectures should have been largely overcome. However, the question is whether the rest of the UK armed forces will be configured to receive and exploit the situational awareness, ISTAR and signals-intelligence data the F-35 will automatically generate whilst flying missions of any type – what the RAF term 'intrinsic ISR'.

The likelihood of the US allowing the export of the MADL and its integration on multiple UK-specific platforms such as the Type 45 and the Typhoon is very low within the next ten years given the Department of Defense's reluctance thus far to put the MADL on any US platform apart from the F-35 for reasons of technological maturity and data security. There are significant security implications for any platform with MADL capability because of the highly classified nature of the data which is automatically shared via the waveform by the F-35. It is, therefore, unlikely that the MADL could be the standard datalink waveform for the UK armed forces before at least 2025–30. Given this restriction, the Ministry of Defence (MoD) would be wise to invest in either the BACN or an equivalent 'translation' capability to convert MADL data into Link 16 and other more prevalent formats. Such a node would be most useful if mounted on platforms which offer long endurance at high altitudes to provide BLOS relay capability from F-35s in heavily contested airspace to other assets at stand-off ranges. Such platforms could be relatively traditional such as the USAF E-11A and RQ-4 Global Hawk, or more radical ultra-long-endurance designs such as Airbus's solar-powered Zephyr-8 UAV which has recently attracted the MoD's attention for just such a role.[46] A BACN-equivalent capability would greatly improve the UK's ability to make use of the F-35's ability to share targeting-quality data via low-probability-of-intercept waveforms

45. Louisa Brooke-Holland, 'The UK's F-35 Lightning II Joint Strike Fighter', House of Commons Library, SN06278, February 2015, p. 13.
46. Andrew Chuter, 'Airbus, UK MoD Deny Deal To Purchase Zephyr UAV', Defense News, 13 September 2015, <http://www.defensenews.com/story/defense/air-space/isr/2015/09/10/airbus-uk-mod-deny-deal-purchase-zephyr-uav/72002140/>, accessed 19 October 2015.

like the MADL with non-MADL-equipped platforms such as the Typhoon, E-3D, Rivet Joint, A-330 MRTT and Type 45. This would not only allow those platforms to support the F-35 with long-range stand-off munitions such as Meteor, Aster 30 and Storm Shadow, but could allow timely PED of potentially significant ISR data not directly relevant to the F-35's tasking, but of potentially great value to other missions. At present, however, policies such as the cancellation of the Joint Data Network as a cost saving initiative in 2011 and the lack of urgency to upgrade the bandwidth available to the QEC, Type 45 and Typhoon are symptomatic of the fact that the RAF and Royal Navy as a whole are behind their US counterparts in efforts to operationalise information-centric warfare and cross-platform connectivity. This will need to change if the UK is to obtain maximum value from its F-35 fleet as the aircraft's long-awaited capabilities begin to mature in the mid-2020s.

The lack of overall combat mass in all three UK front-line services – as well as the proliferation of high-end, anti-access weaponry and an unstable world – makes it essential to get the most out of the limited number of assets available. This not only applies to the F-35 but to all the UK's military assets. Furthermore, if the UK wishes to remain the coalition partner of first resort for the US military, it cannot afford to fall further behind the USAF, US Navy and USMC in bandwidth-dependent, network-centric operating capabilities which will define US military operations in the 2020s. The capabilities the F-35 will potentially offer the UK and the significant changes in ConOps and network infrastructure and training required to make efficient use of them represent a huge potential opportunity to transform the UK armed forces and increase their capabilities against modern, high-end opponents. It should not be wasted.

About the Author

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