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Next Generation Combat Aircraft

Threat Outlook and Potential Solutions

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Contents

Executive Summary

- Three key features of future high-intensity conflict are likely to shape the requirements of next generation combat-air systems.
- Firstly, the increasing density, variety, and resolution of sensors, coupled with powerful post-processing analysis techniques, will make it harder to enter contested airspace undetected. Being difficult to track and target (stealth) will remain valuable, but other elements of the survivability equation – such as speed, agility, electronic warfare, and sufficient combat mass to absorb attrition – may well regain some of their traditional importance.
- Secondly, currently cutting-edge surface-to-air missile systems and sensors will proliferate from Russia and China to countries currently considered to be sub-peer opponents. This will raise the risk and potential costs of air operations overseas. Russia is currently, and will likely remain for several decades, the source of the most capable ground-based air defence systems, as well as electronic-warfare capabilities which can significantly degrade NATO networks and sensors. However, China is emerging as the more potentially worrying source of future combat aircraft which might pose a threat to Western types.
- Thirdly, crucial enablers for combat aircraft such as large prepared airfields/aircraft carriers, aerial refuelling tankers, and the aviation fuel, spare parts, consumables, and munitions supplies on which sustained operations depend will be at risk from both kinetic and asymmetric attacks, including hypersonic missiles, at much longer distances away from the traditional battlespace than ever before.
- Western air forces and politicians have grown used to air operations in low-threat environments with negligible loss rates since 1991. However, attrition from combat losses in the air and potentially due to direct attacks on bases is likely to be a significant feature in any future high-intensity conflict. Being prepared to credibly oppose Russian armed aggression is a core planning assumption for NATO, meaning the fragility of current European air forces due to insufficient combat mass is a cause for concern.
- European combat-aircraft manufacturing countries all have reasons to participate in the development of next generation combat air systems. However, all have different force renewal timelines and pressures, operational priorities, and strategic outlooks. Collaboration will be critical for success given the individually small numbers of platforms which countries can afford to order, and the need to avoid a repeat of Eurofighter and Rafale's mutually harmful competition for exports.
- Due to a variety of political, ethical, and practical factors examined in this paper, operational requirements short of high-intensity, existential conflict are likely to continue to require manned combat aircraft for the foreseeable future. However, the pursuit of overmatch against all potential threats could leave future manned fighters too expensive and prone to programme risk to acquire in the required timeframe and cost boundaries.

- Unmanned combat aerial vehicles (UCAVs) offer a number of key advantages in high-intensity conflict scenarios, including expendability, comparative simplicity of manufacture, and combat endurance. Since UCAVs do not have to be flown regularly and in large numbers to maintain an aircrew cadre, they can be produced in relatively small numbers and regularly upgraded and iteratively improved as the threat picture changes over time, while still representing a potent combat asset. However, there could be political and legal sensitivities around their development in peacetime, since for use in high-intensity warfighting they must be capable of automatic threat recognition, targeting, and lethal weapons release if datalinks are jammed.
- A mix of next generation manned combat aircraft limited to a modest level of technological ambition beyond the capabilities offered by current fifth-generation fighters like the F-35 and F-22, coupled with a stable of regularly evolving UCAVs in low-rate production, could offer both a way to rapidly expand NATO airpower if a crisis appeared imminent, and in a worst-case scenario at least offer a latent capability to replace losses and draw the worst attrition away from scarce manned assets in a high-intensity conflict. A UCAV force would also offer an ongoing project which European combat aircraft manufacturers could more easily collaborate on without the political pressure to agree on a single manned type to procure at scale for half a century or more of future service, and which would provide ongoing work to maintain the skilled workforce and industrial capacity to produce combat aircraft in the long term.

Introduction

THE LATEST EDITION of the UK Air and Space Power Joint Doctrine Publication acknowledges that, as the RAF enters its second century,

> [p]otential adversaries are growing in capability and confidence, challenging our freedom to operate through a proliferation of potent counter-air and space systems and malicious cyber activities. Gaining and maintaining advantage in the air and space domains, alongside our allies and partners, remains crucial to the freedom of action of the joint force.[1]

In other words, a variety of technological and threat trends are converging in ways which threaten the ongoing viability of the now familiar model of Western combat power, which relies heavily on airpower to achieve decisive battlefield and strategic effects. However, this paper does not examine whether a new generation of combat aircraft is the optimal or correct answer to future defence challenges. This is because there are already serious efforts underway in the UK, France, Germany, and the US to produce new combat aircraft and systems over the next fifteen to twenty years.[2] These efforts will be examined in some depth in chapters III, IV and VI. Due to strong political and industrial drivers in these countries, it is highly likely that a new generation of combat aircraft and systems will eventually be procured to first supplement and ultimately replace the current advanced fourth and fifth generation fighters which make up the cutting-edge of NATO's airpower today. This paper examines what shape these efforts might take; sheds light on some of the challenges and drivers; and suggests some potential options for force optimisation. If the UK and other NATO countries are to develop new combat aircraft and associated systems, then conflicting operational, industrial and political drivers need to be discussed and acknowledged early.

In order to better understand the requirements which will shape the next generation of combat airpower, this paper first analyses the high-intensity conflict threat environment which Western defence planners must prepare for in terms of current characteristics and projected development trends, including the potential impact of a return to significant combat attrition. The paper examines the individual priorities and current capability outlook for major Western combat-aircraft-producing states which are likely to be involved in future programmes. Finally, the conclusion explores what sort of characteristics the next generation of combat-air systems might incorporate to most effectively prepare for the prospect of high-intensity conflict against

1. Ministry of Defence, *Joint Doctrine Publication 0-30: UK Air and Space Power,* 5th edition (London: Ministry of Defence, December 2017), p. iii.
2. For the purposes of this study 'combat air system' is used to refer to a combination of airframe(s), sensors, avionics, and weapons which is intended to directly destroy enemy forces on the ground and in the air. The narrower term 'combat aircraft' is used to refer to a singular aircraft type designed to destroy enemy forces on the ground or in the air.

sophisticated near-peer or even peer opponents. A focus on platforms and technical capabilities can never tell the whole story. Concepts of operations (CONOPS), geopolitical circumstances, broader financial, industrial and political realities, and countless other factors all affect the delivery of airpower effects. However, at the core of all these factors, air forces need things that fly in one form or another. Therefore, as a starting point in the broader debate, this paper will focus on what forms they might most usefully take.

Before moving onto the main analysis, however, there is a particular class of unmanned aircraft which are important in considering the shape which future airpower might take. The term unmanned combat aerial vehicle (UCAV) is used in this study to refer to aircraft capable of largely automatic flight and combat operations without requiring a human operator to remotely control the aircraft in real time, as in current generation remotely piloted aircraft systems (RPAS) such as the MQ-9 Reaper. Instead, UCAVs fly missions according to objectives tasked by human operators before and/or during flight, including the detection, prioritisation, and lethal engagement of targets with human supervision rather than direct control. UCAVs are also assumed to be optimised for survivability and lethality in high-threat environments rather than endurance and efficiency in permissive airspace as RPAS are today. It is important to note that artificial general intelligence is not required for UCAVs to be combat effective in high-intensity warfighting as air-superiority, deep-strike, and intelligence, surveillance, and reconnaissance (ISR) platforms.[3] However, currently feasible levels of automation would not replicate the higher judgement functions of a pilot in a manned fighter – rendering UCAVs unsuitable for many other more nuanced and politically sensitive tasks without real-time human oversight.

There are many legal and ethical concerns around how to ensure meaningful human control over UCAVs because of their inbuilt capacity for significant autonomy in target acquisition, discrimination, and lethal engagement. This paper is not intended as a discussion of these issues per se, although two factors are important to consider in this context. Firstly, the political and public risk calculus on the acceptability of pushing human decision-making during sorties further back from the moment of weapons release is tied to a calculation on the significance of human life.[4] This exists on a sliding scale between discretionary conflicts

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3. Artificial general intelligence is a term used to describe theorised ‘general-purpose systems with intelligence comparable to that of the human mind (and perhaps ultimately well beyond)’. See AGI Society, ‘AGI Society’, 2012–2014, <http://www.agi-society.org/>, accessed 27 September 2018.
4. The legal requirements for minimising the risk of civilian casualties during combat operations under International Humanitarian Law (IHL) rest on proportionality. Specifically, the number of civilian casualties likely to be caused by a strike must be proportional to the military advantage expected to be gained. Therefore, civilian casualty/collateral damage calculations are inherently subjective and based on an interpretation of the value of human lives compared to the military objective and situation. This significance of life calculation extends beyond IHL and into political sensitivities in discretionary versus existential conflicts and public tolerance for risk to life in terms of friendly, hostile and civilian groups. In general, during existential conflicts, both the public and politicians are much more likely to accept the employment of high levels of autonomy at

in faraway countries at one end and existential high-intensity conflicts at the other. Secondly, whilst a UCAV suitable for high-intensity conflict would need to be designed with the capability to operate with a high degree of autonomy including lethal-weapons release without real-time human authorisation (due to the likelihood of denied datalink communications in highly contested electromagnetic [EM] spectrum conductions), this requirement would not preclude operating those same UCAVs under much tighter control regimes wherever possible.

Article 36 of the 1977 Additional Protocol I to the 1949 Geneva Conventions requires all new weapons systems to pass a national legal review to ensure they comply with International Humanitarian Law (IHL).[5] In the case of lethal autonomous weapons systems, this has been widely taken to include the requirement to be demonstrably subject to 'meaningful human control' before they can be certified for service.[6] This need not present a problem for UCAVs operating in non-communications denied environments, since real-time human supervision and control of weapons release could be maintained at all times, but the required latent capability to employ lethal force with degraded or denied communications in high-intensity conflict scenarios is controversial. Were UCAVs to be developed by European states, open discussion and debate around IHL compliance early in the process might reduce the likelihood of successful legal challenges or public backlash, as occurred in the early years of RPAS use in Iraq and Afghanistan.[7] These issues are important to bear in mind when considering future combat-air systems, since UCAVs are of great potential significance as will be seen in the concluding chapter of this paper.

Methodology

This study draws primarily on research into NATO combat-air capabilities conducted by the author since 2014, which has included multiple research visits to front line bases as well as frequent and ongoing dialogue with both front line aircrew and capability managers and planners in the US, the UK, France, Germany, Italy, Spain, Norway, Sweden, Denmark, Poland, and other European countries. Specific areas of focus for research throughout this period have

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the moment of weapons release than in discretionary low-intensity conflicts where the military objectives being sought are of lower significance and, as such, the value of lives on all sides are proportionally higher.

5. Vincent Boulanin, 'Implementing Article 36 Weapon Reviews in the Light of Increasing Autonomy in Weapon Systems', SIPRI Insights on Peace and Security No. 2015/1, November 2015. It should be noted that the US is not party to this protocol.
6. Boulanin, 'Implementing Article 36 Weapon Reviews'. For more detailed discussion of Article 36 and meaningful human control requirements, see Heather M Roff and Richard Moyes, 'Meaningful Human Control, Artificial Intelligence and Autonomous Weapons', briefing paper prepared for the Informal Meeting of Experts on Lethal Autonomous Weapons Systems, UN Convention on Certain Conventional Weapons, April 2016, <www.article36.org/wp-content/uploads/2016/04/MHC-AI-and-AWS-FINAL.pdf>, accessed 26 September 2018.
7. As an example of continuing public protests, see *BBC News*, 'Anti-Drone Protest at RAF Waddington', 7 October 2017.

been the capabilities and limitations of advanced fourth generation Euro-canard fighters, the integration of fifth generation capabilities into European air forces following the US Air Force's lead, and the evolution of the Chinese and Russian air- and ground-based threat landscape.

All the research has been conducted at an unclassified level, and the initial findings were discussed and debated during a closed session at RUSI with subject-matter experts from both industry and various NATO air forces to try and keep errors and oversights to a minimum. However, the analysis and conclusions presented in this paper are solely those of the author and are not necessarily representative of the views or comments of any of the officers or militaries which have been so generous with their time and assistance. Likewise, any errors are solely those of the author.

I. The Evolving Threat Picture: Russia on the Ground, China in the Air

THERE ARE CURRENTLY only two countries capable of manufacturing, fielding and exporting ground-based and aerial weapons systems which can seriously threaten Western airpower capabilities: Russia and China. Russia has long been the benchmark for high-end state threats, and it remains the world leader in long-range surface-to-air missile (SAM) and point-defence systems. However, in the realm of advanced combat aircraft, China is increasingly emerging as the primary threat source for Western air forces. Both Russia and China must be understood in terms of their developmental trajectories for technologies and capabilities designed to frustrate the overwhelming airpower advantage held by the West for decades.

The limited wars and Middle Eastern proxy conflicts of the Cold War and the 1990s were disastrous in terms of the reputation of the Soviet, now Russian, combat-aircraft industry. The lopsided kill ratios achieved by Israel against its Soviet-supplied Arab neighbours, and by the US-led coalition against the Iraqi Air Force during the First Gulf War, convinced many that Russian fighter aircraft such as the iconic Mikoyan-Gurevich line were incapable of fighting against Western air forces on anything approaching worthwhile terms. On the other hand, the losses suffered by Israel, the US, and the UK to cheap Soviet-made SAMs and man-portable air defence systems (MANPADS) during these same wars suggested a much more cost-effective area to focus on in order to blunt otherwise devastating air campaigns.[8] Having seemingly learnt this lesson well, Russia has prioritised the development of a series of extremely effective modern SAM systems. By contrast, its attempt to produce a fighter with low-observable features and situational awareness to rival the American F-22 Raptor and F-35 Lightning II has suffered chronic delays and repeated cuts to orders, with the Su-57 programme currently limited to a single squadron of twelve aircraft.[9] Furthermore, Deputy Defence Minister Yuri Borisov stated in July 2018 that there were no longer plans for Russia to put the Su-57 into series production for the foreseeable future.[10]

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8. For example, during the First Gulf War in 1991, the US-led coalition lost 39 fixed-wing combat aircraft to enemy fire, of which only one was destroyed by an Iraqi fighter in air-to-air combat. The rest were destroyed by SAMs, MANPADS, and a few by anti-aircraft artillery fire.
9. Franz-Stefan Gady, 'Russia's Defense Ministry to Ink Contract for 12 Stealth Fighter Jets', *The Diplomat*, 8 February 2018.
10. Franz-Stefan Gady, 'Russia Will Not Mass-Produce 5th Generation Stealth Fighter Jet', *The Diplomat,* 12 July 2018.

The Su-57 itself has a significantly higher radar cross-section (RCS) than either of the two Western fifth generation 'stealth' fighters, being in effect a highly modified derivative of the classic Su-27 Flanker airframe. It prioritises supermanoeuvrability[11] over stealth and whilst it has been designed with innovative low-frequency L-band radar arrays to detect stealth fighters in addition to the higher-frequency fire-control radar in the nose, it is extremely unlikely to be able to match the situational awareness and information superiority which are the other defining characteristics of the latest Western designs. The Russian defence industry is incapable of matching the West in terms of avionics and other capabilities which require high-end microelectronic components such as functional sensor fusion. Since the annexation of Crimea in 2014 and the imposition of Western sanctions against Russia, it has lost access to Western imports of electronic components and efforts such as the Su-57 have suffered accordingly.

Even Russia's more modest efforts to extract the last word in combat performance out of the 1980s vintage Su-27 airframe in the form of the Su-34 Fullback fighter bomber and Su-35S Flanker-E are dependent on Western electronic components which are now inaccessible. The Flanker remains a potent threat within visual range (WVR) for Western fighters due to its famous manoeuvrability and the general lethality of all modern dogfighting missiles, including the Russian R-73 Vympel series (NATO codename AA-11 Archer). However, in the beyond visual range (BVR) arena, which can be safely assumed to dominate in any high-end conventional warfighting scenario, the Flanker family is now outmatched by the latest Western designs. The common Flanker features – a powerful radar to try and 'see first, shoot first', huge RCS, and missiles which are significantly outperformed by the latest NATO beyond visual range air-to-air missiles (BVRAAMs) such as the AIM-120D and Meteor – leave them at a significant disadvantage against the Typhoon, Rafale, and upgraded F-15C, and nearly helpless against the F-22 and F-35. With their large radar, heat, and visual signatures, Flankers are highly unlikely to be able to get close to NATO fighters without being detected at long range, especially by aircraft such as the later F-15s, Rafale, F-22 and F-35 which carry active electronically scanned array radars (AESAs) with advanced low-probability-of-intercept (LPI) capabilities that allow them to actively scan with little chance of being detected themselves. The Flanker series currently lacks such capability.

As a result, Flanker pilots must predominantly rely on active scanning to try and detect NATO fighters early, with powerful radars such as the Su-35's Irbis-E. However, this means that they will almost always be passively detected by the advanced radar-warning receiver/tracking capabilities of the latest Western fighters before the Flankers themselves can obtain a target track. The basic physics of radar means that without the latest LPI capabilities, a radar which is actively scanning can usually be detected by a radar-warning-receiver (RWR)-equipped adversary significantly further away than the range at which the radar can receive its own echoes in order

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11. Supermanoeuvrability is the ability to maintain control over the direction of the aircraft's nose whilst outside aerodynamic flight. In other words, whilst the aircraft's wings are stalled at very high angles of attack (alpha) and/or negative airspeeds, the use of thrust vectoring and a digital flight control system allows the pilot to retain directional control.

to obtain a track/lock.[12] In other words, a Flanker pilot must try to detect an opponent at long range to avoid being destroyed. But active scanning will give away their position, allowing hostile fighters with superior passive tracking and/or LPI radar capabilities to get the first shot in. The relative inferiority of the Russian R-77 series BVRAAMs (in terms of range and energy retention) to Meteor and the latest AIM-120C7/D only increases the disadvantage. Finally, the F-22 and Typhoon in particular can operate at higher altitudes and sustained speeds than any Flanker during BVR combat, further increasing the range advantage of their missile shots.[13]

Russia's economic limitations and the many competing demands across its full-spectrum armed forces make it unlikely that Russia will develop significant numbers of combat aircraft capable of seriously threatening Western control of the air in symmetric terms over the next 20 years. With the acknowledgement that the Su-57 – itself a highly modified Su-27 – will not enter series production, the Russian military aviation industry has admitted its failure to develop any new combat aircraft beyond evolutions of Soviet-era Mig-29, Su-27, and Mig-31 families. These have more or less reached the limits of their development potential.

Russia's ground-based air defence capabilities, however, are another story entirely. Russia's modern air-defence systems are far more capable than their Cold War progenitors, albeit not deployed in the same density as was common near the Fulda Gap in the late 1980s. The very-long-range S-300V4 and S-400 are particularly worthy of scrutiny. This is not only because they are available to almost any state with the money to buy them and, therefore, represent a significant threat-proliferation risk, but also because their range of up to 400km against higher-flying aircraft makes them capable of holding other countries' capabilities at threat far outside the deploying state's own borders. For example, S-400 systems in Kaliningrad can threaten NATO aircraft over most of the Baltic States and Poland as far away as the German border. In these 'strategic SAMs', as they are sometimes referred to, Russia has developed ostensibly defensive airpower capabilities which can nonetheless be used to threaten and contest neighbouring states' aerial freedom of action over considerable distances.

The S-400 is currently the pinnacle of the long-running S-300 family of SAMs developed in various forms for the Soviet and Russian ground forces, navy, and strategic rocket forces. Each S-400 fire unit (battalion) includes a command vehicle, wide-area scan and tracking radar, fire-control radar, and optional anti-stealth low-frequency/passive radar modules, in addition to eight transporter erector launcher (TEL) vehicles which carry and fire the missiles themselves. The system is highly mobile, has a certain level of built-in redundancy, and is designed to be integrated into a larger, layered air-defence network. This mobility and extremely long engagement range makes Russian strategic SAM systems difficult to track and target compared to older generation SAMs, whilst the radar units are digital and capable of frequency-agile operations to frustrate traditional signal-analysis based jamming and triangulation. Even if hostile forces manage to find, track, and launch stand-off missiles or other precision-guided munitions against an S-400 battery, each one

12. For more information on the Radar Range Equation, see *CopRadar.com*, 'Radar Range Equation', <https://copradar.com/rdrrange/>, accessed 18 July 2018.
13. Author's calculations.

is defended by at least two Pantsir-S1/2 point-defence SAM/gun systems which are designed to intercept such threats. The S-400 itself has been designed with considerable capabilities against incoming cruise and ballistic missiles for both self-defence and defence of nearby installations. Hence, multiple, near-simultaneous weapon deliveries are likely to be required for ‘hard kills’ against S-400 systems, which further complicates suppression or destruction of the adversary’s forces. Western air forces can locally suppress or saturate individual S-400 batteries and other SAMs during a conflict, but such efforts would pose substantial risks to aircraft involved and would struggle to ‘hard kill’ a sufficient number of dispersed launchers/radars to prevent these systems from posing a persistent threat.

To achieve extremely long maximum engagement ranges without compromising shorter-range missile manoeuvrability against agile targets, the S-400 is designed to employ four different types of missile, ranging from the short-range 9M96E (for engagement at up to 40km) up to the 40N6 missile (with an advertised range of up to 400km). The 40N6 has suffered from numerous developmental problems, especially with its active radar-seeker head designed to prosecute targets without requiring the ground-based fire control radar to paint said target throughout the entire engagement sequence. However, recent announcements suggest that it is nearly ready for front-line service, which would finally enable S-400 systems to actually strike aircraft at their much-vaunted maximum range.[14] At ranges inside 250km, the S-400 and other strategic SAM systems tend to employ smaller, cheaper missiles with greater agility in the terminal homing phase than the huge 40N6.[15] The result is that Russian SAMs are a serious threat to larger, high-flying Western aircraft such as refuelling tankers, airborne warning control systems (AWACS), high-altitude UAVs, and transports at ranges up to 400km. This has the effect of forcing these assets to operate significantly further away from the front line areas than in previous conflicts. Russian SAMs are also a serious threat to modern fighter aircraft within approximately 200km – and they will only become more capable as Russia irons out the remaining limitations in its missiles’ high-altitude cruise, look down/shoot down capabilities for over-the-horizon engagement capabilities against low-flying targets at long ranges.

The S-400’s command-and-control system was designed to be modular from the ground up, to allow the integration of multiple different types of specialised radars including the anti-stealth Protivnik-GE ultra-high frequency and Nebo-M very high frequency AESA radars, as well as more exotic equipment such as the Moskva-1 ‘passive radar’ sensor.[16] This system architecture allows new breakthroughs in detection and tracking capabilities, especially against very-low-observable threats such as the F-35 and F-22, to be rapidly integrated into S-400 units in the field. Such modularity also allows the S-400 to act as a situational-awareness and engagement-capacity

14. Karl Soper and Neil Gibson, ‘40N6 Missile for S-400 System Could Enter Service “Soon”’, *Jane’s 360*, 8 April 2018.
15. For more information on the component parts of the S-400 system, see *Army Technology*, ‘S-400 Triumph Air Defence Missile System’, <https://www.army-technology.com/projects/s-400-triumph-air-defence-missile-system/>, accessed 9 October 2018.
16. J R Wilson, ‘New Frontiers in Passive Radar and Sonar’, *Military and Aerospace Electronics,* 8 February 2016.

multiplier for older SAM systems by integrating those older systems as extra 'shooters' within its own architecture. Here it is also worth mentioning that both Russia and China continue to invest heavily in exotic, albeit unproven and immature detection techniques. These include: coherent passive location (CPL) systems, which listen for reflections and doppler-shift patterns in third-party electromagnetic emissions; exploiting bistatic anti-stealth techniques; and even quantum radar which involves using quantum-entangled particles to provide detailed information about even stealth aircraft whilst remaining impossible to jam or detect.[17]

For the time being, not content with the S-400's formidable level of capability, Russia is investing in a new variant – codenamed S-500 – with greater anti-ballistic missile capabilities as well as longer range against aerodynamic targets. The fact that the legacy S-300 system continues to be refined in the shape of the S-300V4/Antey 2500 system for both Russian service and for export customers also points to the S-400 itself continuing to receive upgrades to missiles, radars and command vehicles for the next several decades. The S-400 is therefore likely to be a key threat for which NATO's current and future combat-air systems will have to prepare.

Russia also places a great deal of importance on electronic warfare (EW) at the tactical and strategic level to disrupt the datalinks and sensor capabilities at the heart of NATO CONOPS. Ben Hodges, then commander of the US Army in Europe, famously described Russian EW capabilities in Ukraine as 'eye-watering' in 2015.[18] Examples of modern systems developed specifically to jam radar-based sensors, datalinks and even precision-guided munitions include the ground-based Krashuka-4/2O and Borisoglebsk-2 series, and the helicopter-mounted Rychag-AV system.[19] Russia's ground forces are also equipped with a wide variety of smaller, but potent vehicle- and tactical-UAV-mounted EW equipment at battalion level and above.[20] NATO forces would find that the performance of active sensors, datalinks and precision-guided munitions would be significantly degraded in any conflict with Russian forces. Of course, Russian EW efforts would not have things all their own way and certainly not all the time, but NATO forces are much more heavily dependent on assured access to networks, tactical datalinks, and the provision of real-time ISR, and so would suffer a relatively greater drop in combat effectiveness due to a heavily contested EM spectrum.

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17. For information on CPL systems, see John Venable, 'Operational Assessment of the F-35A Argues for Full Program Procurement and Concurrent Development Process', *Backgrounder,* No. 3140, Heritage Foundation, 4 August 2016, p. 5. Quantum radar as a practical concept remains controversial and unproven but is an area of ongoing study in China, the US, Russia, and Canada. For background information on quantum radar, see Sebastien Roblin, 'Quantum Radars Could Unstealth the F-22, F-35 and J-20 (Or Not)', *The National Interest*, 10 May 2018.
18. Ben Hodges speaking at a conference, quoted in Paul Mcleary, 'Russia's Winning the Electronic War', *Foreign Policy*, 21 October 2015.
19. For examples of Russian EW products openly advertised, see *TASS*, 'Russia's Cutting-Edge Weaponry Capable of "Blinding" Enemy's Army', 19 April 2017.
20. For more information, see Igor Sutyagin with Justin Bronk, *Russia's New Ground Forces: Capabilities, Limitations and Implications for International Security,* RUSI Whitehall Paper 89 (London: Taylor and Francis, 2017), pp. 80–82.

Russia's dominant CONOPS in conventional force-on-force terms in the event of a conflict with NATO relies predominantly on mobile and survivable long-range SAM batteries shielded by powerful EW assets, coupled with more numerous medium-range and point-defence SAM and anti-aircraft-artillery systems. These would limit the freedom of action of NATO combat aircraft, inflicting steady losses. They would be coupled with denying the use of NATO forward air bases with ballistic and cruise missile strikes, as well as limited strikes with conventional combat aircraft, deep-infiltration agents, and special forces. Of course, Russian grand strategy aims to avoid a direct conflict with NATO since the latter has much greater overall resources. Russia concentrates in day-to-day terms on information and cyber warfare, as well as proxy operations and subversion.[21] However, none of these are the direct responsibility of air forces to counter. For the purposes of this study into future combat aircraft and systems, Russia's SAMs, electromagnetic-spectrum and asymmetric airfield-denial capabilities are of more concern.

China's own HQ-9 series of SAMs was developed on the basis of Russia's S-300V, with more modern Chinese electronics. As such, the HQ-9 variants are also modular in terms of radar and missile types and have been developed for land-mobile and naval installations. Whilst China will no doubt continue to develop its domestic strategic SAM arsenal, its continued eagerness to purchase limited numbers of the expensive S-400 speaks to the continued Russian lead in this area of capability.[22]

In terms of airborne threats, however, China should now be considered the most likely source of future platforms able to threaten Western air dominance. For many decades the People's Liberation Army Air Force (PLAAF) was reliant on obsolescent fighter and strike aircraft imported from the Soviet Union or domestic derivations of such types. Whilst some of these, such as the Mig-21 derived Chengdu J-7, are still in service, the majority of the PLAAF's front line fighters are now either modern Russian or Chinese manufactured Su-30/J-11/J-16 Flanker variants, or China's own domestically developed J-10A/B series multi-role fighters. The PLAAF has also inducted its first operational stealth fighter, the Chengdu J-20A, which deserves some scrutiny.

The J-20 is a large, low-observable (stealth) strike fighter with obvious design elements from both the F-35 and F-22. These are likely drawn from a combination of using proven airframe, intake, cockpit, and wing shapes from readily available imagery of these American stealth fighters as a starting point. They further incorporate insights gleaned from the industrial-scale Chinese military and commercial espionage campaigns carried out over more than a decade against Western defence-industry entities and armed forces.[23] However, despite having drawn on Russian military engine technology to develop the domestic WS-15 which

21. For more detailed discussion of how Russian asymmetric warfare doctrine involves seeking to avoid the use of military violence, see Rod Thornton, 'The Russian Military's New "Main Emphasis": Asymmetric Warfare', *RUSI Journal* (Vol. 162, No. 4, October 2017).
22. *TASS*, 'Russia Begins Delivery of S-400 Missile Systems to China — Source', 18 January 2018.
23. For example, see text on Grand Jury indictment of Su Bin for cyber espionage targeting military aircraft programmes in Department of Defense, 'Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2015', 2015, p. 55.

powers the production aircraft, and incorporated many design elements copied from American stealth-fighter programmes, the J-20 still represents a distinctly Chinese manifestation of these different elements which, in its final form, is unlike anything produced so far by either Russia or the West.

With its large overall size, twin engines, forward canards, and small vertical tail surfaces, the J-20 has clearly been designed to prioritise range on internal fuel, large internal weapons capacity, and significant agility for WVR engagements, at the cost of higher-end low-observable properties.[24] As such it will be easier to detect on radar, especially due to its forward canards and ventral stabilising fins, than either the F-22 or F-35. However, it will have good manoeuvrability for its size and excellent range on internal fuel, with the capacity to extend this further with up to four jettisonable external fuel tanks at the cost of greatly reduced stealth properties while they are attached. Furthermore, the large weapons bays will allow long-range missiles, anti-ship missiles, or other sizeable strike munitions to be carried without compromising its RCS. The J-20 also benefits from Chinese efforts to close the gap with the US on AESA radar technology, having already fielded initial versions on its indigenously upgraded J-11 and J-16 Flankers. There can be little doubt that Chinese radar technology will within the next decade or so allow the J-20 and other Chinese fighters such as the J-10, J-11, and J-16 series to exploit similar LPI capabilities that are currently the sole preserve of the latest Western designs, with consequent implications for the effectiveness of RWRs and passive tracking. Furthermore, the early production J-20A airframes currently in service with the PLAAF incorporate what appears to be a copy of the F-35's electro-optical tracking system in the same position under the nose, suggesting China also sees merit in developing wide-aperture passive tracking, warning, and designation systems. The J-20 represents a significant potential threat to Western airpower since it should be low-observable enough to be very hard to detect against the background noise of any large-scale military clash, and with the organic range and weapons capacity to hunt down critical enablers such as tanker and AWACS orbits, as well as potentially striking bases and shipping.

Given the huge disparity in programme funding and the fact that the US has decades of experience developing the F-22 and F-35, it is unlikely that the Chinese can yet match the crucial sensor-fusion and multi-spectral situational awareness which US fighters can generate.[25] However, the rapid pace of iterative development exhibited by the Chinese military complex in the past two

24. Author's calculations and analysis.
25. Chinese military spending is highly opaque, but figures quoted by Chinese media outlets suggest that at least 30 billion yuan ($4.4 billion) has been spent on the development of the J-20. See Liu Zhen, 'J-20 vs F-22: How China's Chengdu J-20 'Powerful Dragon' Compares with US' Lockheed Martin F-22 Raptor', *South China Morning Post*, 28 July 2018. By contrast, the total cost of the F-22 Raptor programme was around $70 billion, of which around $30 billion was spent in development and initial production set up. For discussion, see Tyler Rogoway and Joseph Trevithick, 'Here's the F-22 Production Restart Study the USAF has Kept Secret for Over a Year', *The Drive*, 4 May 2018. The F-35 programme meanwhile is currently expected to total $406.5 billion for development and acquisition. See Anthony Capaccio, 'Lockheed F-35 Cost Stabilizes at $406 Billion, Pentagon Says', *Bloomberg*, 13 March 2018.

decades is much quicker than in the US and other NATO countries. Since it shows little sign of slowing, it is most likely a question of when, not if, the PLAAF will catch up at the high end of combat-aircraft design. So far, the J-20A has not been offered for export, but China's aggressive expansion in the military export market in general should caution against assuming it will keep its high-end combat aircraft off the global market.

II. The Inescapability of Attrition and the Need for Combat Mass

WESTERN AIR FORCES and, perhaps more importantly, the political leaders who control their funding, have been lulled by two and a half decades of air dominance and operations in largely permissive environments into an assumption that significant combat losses and attrition are a thing of the past. However, the threat of conventional conflict against Russia on NATO's Eastern Flank – as well as the proliferation of Russia's radars and SAM systems and potentially Chinese combat aircraft in the near future – suggest a need to urgently rethink this assumption. The last time the US faced an adversary who shot back during a sustained conflict, it lost more than 2,400 fixed wing and more than 5,600 rotary wing aircraft to North Vietnamese fire during the war in Southeast Asia between 1964 and 1972 – despite the US's undeniable technological superiority in the air.[26]

There is a temptation to discount the relevance of air campaigns in Vietnam, the Iran–Iraq War, and the Falklands to modern air operations; modern operations have smaller numbers of aircraft which are hugely more capable, sophisticated, and reliable. Furthermore, the capability of air-launched missiles, stand-off munitions, jammers and other payloads have increased at a greater rate in the West than other parts of the world.

Nonetheless, technological advantages do not necessarily rule out significant attrition in high-intensity combat, since the threat systems which Western air forces could face are also much more capable than in previous decades. Today it is widely accepted that the US – and more so its European NATO Allies – face a significant erosion of their technical superiority in the face of Russian and Chinese ground-based and Chinese aerial weapons systems and sensor technology. Senior military planners such as General Carlton Everhart, the chief of Air Mobility Command (United States Air Force – USAF), are once again talking publicly about the need to plan for

26. For US Air Force fixed-wing losses, see 'A Comparative Analysis of USAF Fixed-Wing Aircraft Losses in Southeast Asia Combat', Air Force Flight Dynamics Laboratory, 1977, p. 4, <http://www.dtic.mil/dtic/tr/fulltext/u2/c016682.pdf>, accessed 18 July 2018. For US Navy and US Marine Corps losses, see 'Aircraft Losses in Vietnam', Naval History and Heritage Command, <https://www.history.navy.mil/research/histories/naval-aviation-history/involvement-by-conflict/vietnam-war/aircraft-losses-in-vietnam.html>, accessed 18 April 2018. For rotary-wing losses, see Gary Roush, 'Helicopter Losses During the Vietnam War', Vietnam Helicopter Pilots Association, February 2018, <https://www.vhpa.org/heliloss.pdf>, accessed 18 July 2018.

combat attrition when designing force structures to mission requirements.[27] Put simply, whilst individual European platforms are not outclassed by Russian capabilities in many cases, they must nonetheless be expected to suffer significant attrition. This is problematic because based on current force structures, most NATO air forces cannot cope with attrition on any significant scale without a rapid degradation of combat effectiveness.

For the US, planning for significant combat attrition in a future high-intensity conflict is a deeply uncomfortable but nonetheless feasible exercise due to the sheer number of combat aircraft (over 2,500) and enabler assets which the USAF, US Navy and US Marine Corps possess. Even so, the USAF recently pitched for a significant expansion in squadron numbers due to high-intensity planning considerations. Furthermore, the US practice of maintaining large mothballed reserve fleets and the country's huge industrial capacity, coupled with geographical distance from potential threats, means that reasonably rapid reconstitution of forces is not an insurmountable challenge.

European countries, however, enjoy no such advantages. The largest European air forces – the RAF, Armée de l'Air, Luftwaffe, and Aeronautica Militare – all maintain fast jet fleets of fewer than 300 aircraft, whilst most others operate much smaller fleets of 30 to 60 aircraft. It is worth remembering that in any fleet the actual number of aircraft available at any given time for front line operations will be somewhere between 20–50%, depending on maintenance cycles, threat situation, and platform reliability. In the event of an unforeseen crisis, weapons stockpiles, spares availability, and consumables would also significantly reduce the number of combat-capable jets available at short notice.

All this together means that combat attrition is likely to be an extremely difficult factor for European air forces in planning for high-intensity warfighting. Even reasonably low loss rates on any kind of sustained basis would quickly hollow out deployable front line strength. Official estimates of the likely combat persistence of various air forces in high-intensity combat operations against Russia in defence of Eastern NATO Allies are highly classified and, hence, not available to the author. Moreover, the length of time before air forces would start to run out of combat-capable aircrew, airframes, bases, and weapons stocks would be affected by many factors, including the geographical boundaries of a combat zone, the rules of engagement being followed by both sides, and the urgency to break through to beleaguered friendly forces. Nonetheless, the author found that an underlying assumption of a limit of around two to four weeks of high-intensity operations against Russian conventional forces in Eastern Europe was not seriously questioned in numerous conversations since 2015 with force planners and operational aircrew in even the larger European air forces.

For the smaller air forces able to sustainably deploy six to ten fighters out of total fleets of 30–60, such as the F-16 countries, even a week of high-intensity conventional combat could easily see their usable forces depleted and barely able to conduct defensive patrols over their own

27. Comments by Carlton Everhart reported in Sydney Freedberg, 'US Needs More Tankers, Transports Since Russia & China Can Shoot Them Down', *Breaking Defense*, 21 September 2017.

territory – assuming they maintained sufficient weapons stockpiles, and other consumables such as decoys, to conduct sustained operations at short notice to begin with. The default answer to such concerns is that each state would certainly not fight alone, and NATO as a whole has a large advantage in combat airpower over Russia. The majority of European NATO fast-jet fleets are not combat ready at any given moment, however, whilst spares and weapons stockpiles remain low almost across the board. Dependence on the USAF for air-to-air refuelling, suppression/destruction of enemy air defences (SEAD/DEAD), dynamic ISR and targeting, and satellite communications – to name but a few areas – remains extremely high, especially outside the RAF and Armée de l'Air. Most American airpower is spread around the world, and whilst there would almost certainly be rapid movement of large amounts of capability into Europe at speed, there are many global commitments which the US would have to devote significant forces to cover, especially in such a politically explosive scenario.

Attrition in the air, likely to be predominantly inflicted by Russian ground-based integrated air defences rather than fighter aircraft, might not even be the biggest drain on NATO front line strength: airbases throughout Europe would be very likely to be attacked during any active combat scenario with Russian forces. NATO's air forces are concentrated on far fewer bases than during the Cold War, and in many cases have little or no effective defences against cruise and ballistic missiles, swarms of micro-UAVs, or indirect fire. They are also potentially vulnerable to Russia's extensive and aggressive array of special operations forces and sleeper agents. Furthermore, both Russia and China are actively developing hypersonic cruise and glide-vehicle type missiles which would allow them to bypass all known defence systems with very limited warning times from launch detection – a trend which will further increase the vulnerability of critical infrastructure such as large airbases. Given the qualitative advantage of Western aircraft, and the very high proportion of NATO's overall deliverable firepower which they represent, it would be an obvious tactic for Russia to attack airbases at every opportunity during the initial phases of any conflict to deny their use as staging areas and destroy as many aircraft as possible on the ground.

In the face of likely attrition and the limited deployable fleets available, most European air forces simply do not possess enough aircraft, aircrew, weapons, and enablers to maintain combat effectiveness during any moderately protracted period of high-intensity conflict. Whilst Russian aircraft would certainly suffer even higher loss rates, the core threat from modern, mobile, long-ranged SAM systems protected by EW and point-defence systems would be much more likely to prove a persistent one despite temporary gaps created by successful SEAD/DEAD operations.

In terms of possible reconstitution, the fact that there are three different fighter aircraft currently in production, coupled with small fleet sizes, means that European fighter production lines are scaled to deliver small numbers of airframes on a multi-year basis to enable them to stay open longer whilst they seek export opportunities. The flip side of this approach is a much smaller capacity than their American equivalents to ramp up production quickly, and at short notice they certainly do not have the capacity to make good losses beyond a dozen or so aircraft a month. Even this would mean diverting aircraft bought and paid for by overseas customers, although in the case of a major war that would probably be done out of necessity.

Moreover, beyond the aircraft already lined up for production, the immense complexity and global nature of the supply chain for fighter manufacturing means that in the event of a major conflict, the required subsystem components might be hard to obtain, at least in time and in sufficient quantities.

There would also be a critical shortage of pilot-training capacity since it takes experienced qualified flying instructors (QFIs) and qualified weapons instructors (QWIs) to train new fast-jet pilots. These QFIs and QWIs are already in short supply in most NATO air forces, and in the event of high-intensity conflict would be desperately needed at the front line and so they could not be easily pulled back to the training pipeline to suddenly expand it. Shortages in fast-jet aircrew due to combat losses and strain might be partially remedied in the short term by bringing back former aircrew currently serving in desk roles. However, it still takes time and good instruction to regain proficiency. Former aircrew would also still need live flying hours and safe airspace, as well as simulator facilities, to familiarise themselves with the latest tactics, techniques and procedures. In short, training new pilots to fly new aircraft would be very difficult to accomplish at scale, even if enough aircraft could somehow be produced in useful time.

III. France and Germany: The Continental Mainstays

FRANCE AND GERMANY have been instrumental to the development and fielding of advanced fighter aircraft since the dawn of combat aviation. Today, both are unique in terms of their impact on the fighter development market, and both still have an economic (and therefore procurement) potential which places them at the high end of the order numbers and workshare divide in any future programme. However, both also have significant issues as partners in any potential multinational development endeavour.

Traditionally, France has been fiercely protective and supportive of its indigenous combat-aircraft industry – with an almost unbroken line of domestic development success stories from the pioneering Morane-Saulnier and Nieuport types of the First World War, to the iconic Mirage series and modern Rafale today. This has also traditionally stood in the way of French participation in multilateral development efforts – with the SEPECAT Jaguar a notable exception. Nonetheless, the Future Combat Air System (FCAS) team in the Armée de l'Air today are looking towards a bilateral Franco-German or multilateral European development programme to supplement and eventually replace the Rafale in the early 2040s.[28] Whilst France has maintained sufficient industrial expertise and capacity to attempt a significant redesign and upgrade of the Rafale – something it will do in the absence of an acceptable development partner – it cannot afford to develop a genuinely next-generation combat-air system alone. France is, therefore, more open to collaborative development of a next generation combat-air platform or system than it was during the early years of what became the Eurofighter programme.

Nevertheless, France still maintains some specifically French performance and capability requirements borne primarily out of the delivery role of France's nuclear deterrence force (la force de dissuasion nucléaire) and the enduring Armée de l'Air planning requirement to be able to operate from the French mainland deep into Africa at short notice and sustain combat operations from overseas bases once deployed.[29] This places demands on ruggedness and range unlikely to be matched by other potential development partners that are primarily concerned with continental European defence and potentially expeditionary warfare from large coalition bases. However, due to the stand-off missile-based nature of the French air force's nuclear deterrent mission, and the long range (with external tanks) and ruggedness of the Rafale, these are current capabilities which France wishes to maintain or ideally improve in a next generation system, rather than a source of concern for capability gaps which need to be filled. It is also

28. Gareth Jennings, 'ILA 2018: Governments Approve Franco-German Future Fighter, Outline Other Co-operative Defence Projects', *IHS Jane's Defence Weekly*, 26 April 2018.
29. Author interviews with senior officer in FCAS programme office, Armée de l'Air, Balard HQ, Paris, 9 April 2018.

worth considering that any Rafale replacement may be required to be navalised and carrier-capable, to enable it to replace the Aeronavale's Rafale-M as well as Armée de l'Air versions.

In the current French force structure with Rafale at its core and with a limited number of Mirage 2000 units remaining, which will continue to be slowly phased out and replaced with more Rafale through the course of the next decade, France has built an air force extremely well equipped for operations in limited wars in Africa; in support of Western counter-insurgency; and in overseas intervention operations against near-peer opponents. However, what the Rafale's highly regarded mix of a strong EW suite, varied and heavy ordinance delivery options, and general versatility cannot give the Armée de l'Air is a sufficiently resilient force against peer opponents fielding the latest airborne and ground-based threat systems. The balanced and impressive overall capability mix of the Rafale and current-generation weapons systems is insufficient to prevent unsustainable losses if committed to sustained high-intensity operations against modern air defences. Stand-off munitions – especially the SCALP missile – still require real-time targeting track-grade data to hit mobile threats such as modern Russian and Chinese SAM systems and radars, and must be fired from too far out for that data to come from the Rafale's onboard sensors whilst remaining out of hostile engagement range.

Consequently, France is involved in both the FCAS working group discussions with the UK on the basis of the BAE Systems Taranis and Dassault/Saab nEUROn UCAV technology demonstrators, and also the next generation combat-aircraft development effort with Germany to replace the Rafale. For France, the primary driver for next generation combat-air systems is to find a way to shift the burden of attrition away from scarce manned assets such as Rafale or any manned successor. Whether this is through the use of unmanned 'wingmen', advanced expendable decoys, revolutionary EW, or multi-spectral low-observability is still up for discussion. However, one thing is clear from the French standpoint – there is a lack of faith that it will be possible in the 2030s and beyond to enter the battlespace undetected, whether by relying on advanced stealth features or otherwise.[30] Therefore, the French approach seems likely to emphasise expendable decoys, EW, and airframe performance in addition to pursuing 'stealthy' signature reduction and onboard situational awareness.

Germany is in a different position. Whilst there are compelling political reasons for co-operating with France on the development of next-generation military equipment, Germany's strategic outlook is very different, leading to correspondingly different priorities for future capabilities. On paper, the Luftwaffe has maintained formidable air-defence and adequate strike capabilities over the past decade with its Tornado and Eurofighter Typhoon fleets. But Germany's relatively low military spending, coupled with the country's entrenched anti-interventionist post-war outlook, has ensured that not only are readiness and modernisation states extremely poor compared to most European air forces, but the Luftwaffe itself is stuck with a deeply defensive doctrine and political role. This does not fit easily with the proactive interventionist stance which France has taken in recent years in Libya, Mali, and Syria, in which airpower has played a

30. Author interviews with senior officer in FCAS programme office, Armée de l'Air, Balard HQ, Paris, 9 April 2018, and Rafale pilots at various locations and times throughout 2018.

leading role. Like France, Germany has chosen not to procure a low-observable fifth-generation fighter, and as such lacks the ability to operate within airspace defended by modern Russian or Chinese ground-based air defence systems without incurring prohibitive losses – unless enabled by allies with more advanced stealth and SEAD/DEAD capabilities. The traditional answer of the Tornado ECR with HARM missiles for the SEAD/EW escort role is now completely outclassed in terms of range and capabilities by the current generation of Russian SAMs. The extent of the threat growth can be seen in the fact that the engagement zones of Russian S-400s in Kaliningrad almost reach Germany's eastern border if/once the 40N6 missile is operational.

For Germany, defence of NATO airspace and a notional capability to contribute fire support from the air to Allied ground units on NATO soil during a conventional attack scenario are the only significant operational drivers for future capability.[31] Even the longstanding B-61 nuclear delivery role currently performed by a small part of the Tornado force is considered operationally irrelevant and politically too inflammatory to discuss publicly, especially in terms of replacing the Tornado in the delivery role with Eurofighter Typhoon or a future combat-air system. Again, this contrasts starkly with the heavy emphasis and investment placed on the airborne component of France's nuclear triad which is set to continue to be a role for whatever replaces the Rafale. In recent years, German politicians have shown a willingness to extend the Tornado's nuclear-delivery role far beyond what its operational credibility or survivability should allow. Furthermore, the poor state of airworthiness and combat readiness in its Eurofighter Typhoon fleet[32] and extreme shortage of munitions suggests that German decision-makers are unlikely to be swayed by a projected lack of current and future Luftwaffe capacity to avoid significant attrition in the event of a high-intensity conflict, or sustain such attrition without a rapid deleterious effect on combat effectiveness. Despite significant political shifts since 2014, high-intensity conflict as a defence-planning task is still not considered credible in Germany and, as such, is not accorded anywhere close to sufficient resources.

However, if the pressure applied by successive US presidents Barack Obama and Donald Trump successfully pushes German defence spending closer to the Wales commitment of 2% of GDP by 2024, then this might well change.[33] Although German Chancellor Angela Merkel announced in mid-2018 that Germany was only on course to reach 1.5% by that time,[34] projected economic growth would still lead to a large amount of extra funding – at least some of which could well find its way into the future fighter effort with France. An ambitious new combat-aircraft programme would provide a significant boost to the German aviation sector – just as the Eurofighter programme did for Airbus in the 1990s and 2000s – with greater potential second-order benefits than many other ways to spend additional defence funding. In other words, whilst there is little

31. Author discussions with serving and recently retired Luftwaffe officers, Munich, Berlin, and London, 2017 and 2018.
32. For example, see Chase Winter, 'Only 4 of Germany's 128 Eurofighter Jets Combat Ready — Report', *Deutsche Welle,* 2 May 2018.
33. Article 14 of the Wales Summit Declaration, 4–5 September 2014.
34. *Deutsche Welle*, 'Merkel Says Germany Won't Make NATO Spending Target Until After 2024', 15 June 2018.

to suggest any serious German ambition to develop a new generation combat-air system for operational capability reasons, the development of such a programme might be a natural home for future increases in German defence spending once initial holes in readiness and existing equipment modernisation are addressed.

For France, Germany may be the ideal partner from a political and economic point of view – but remains a problematic bilateral partner for the development of next generation combat-air systems due to its lower levels of ambition for operational capabilities. In terms of operational requirements, the UK still offers a potentially more suitable partner to France.

IV. The UK and Team Tempest

THE CENTREPIECE OF the UK's new combat-air strategy, Team Tempest, was unveiled in mock-up form by Secretary of State for Defence Gavin Williamson on the first day of the Farnborough Air Show 2018.[35] £2 billion will be allocated to the Combat Air Strategy between 2018 and 2025 to start the development of a new combat-air system with BAE Systems and Italian defence firm Leonardo as the initial industrial leads, with an ambition to collaborate with other European (and potentially even US or Japanese) partners. This was a major announcement, not least since the UK's public commitment to purchase 138 F-35 jets would mean taking delivery of these aircraft well into the 2030s – a factor which had until recently been assumed by many to rule the UK out of participation in a future European-led combat-air development programme during the 2020s. It was a signal of British political intent to remain an important player in any future European combat-aircraft project, despite the F-35, the difficulties of Brexit, and intense competition for increasingly stretched defence funding.

UK requirements for future combat-aircraft capabilities are somewhat unclear at this stage since at the time of writing the F-35 force is still in workup towards its declaration of initial operational capability. The process of adapting the Royal Air Force and Royal Navy's structures and doctrine to best leverage and take advantage of the fifth generation jet's capabilities is still in its early stages.[36] As a result of this, and the anticipated 40-plus-year useful lifespan of the F-35 as a platform, most UK future combat-air capability scoping work in the past decade has been centred around future-proofing the F-35 well into the 2040s rather than attempting to define requirements for a replacement for Typhoon in the same timeframe. However, the Team Tempest initiative shows a change of focus. The initial mock-ups unveiled at Farnborough show a large twin engine, low-observable concept which suggests a replacement for Typhoon, specifically in the air-superiority and long-range-patrol/strike roles for which the F-35 is not ideally suited from an airframe design perspective.

Against the current Russian threat outlook, the combat-air mix with which the UK will operate in the 2020s and 2030s – F-35B and Typhoon – is relatively well suited in terms of individual platforms. The Typhoon is an excellent quick-reaction alert/air-superiority fighter designed from the outset to counter Russian Flanker-series fighters, and is well suited to the role. Meanwhile, the F-35 is designed to penetrate and operate inside airspace heavily defended by Russian ground-based air-defence systems. The two fighters complement each other's strengths

35. For a more detailed analysis of the initial elements of the Tempest project mock-ups, see Justin Bronk, 'Enter the Tempest', *RUSI Defence Systems*, 16 July 2018.

36. For more detailed analysis of the challenges and opportunities of integrating the F-35 into the RAF and Royal Navy, and how the latter needs to change in order to make good use of the jet, see Justin Bronk, 'Maximum Value from the F-35: Harnessing Transformational Fifth-Generation Capabilities for the UK Military', *Whitehall Report,* 1-16 (February 2016).

when operating together. However, as previously discussed, Typhoon and even the F-35 – whilst individually more than a match for the Russian hardware they were designed to combat – are unlikely even today, let alone for the next decade and a half, to offer sufficient technological overmatch to avoid significant combat losses in high-intensity warfighting against Russia. In other words, the UK's largest problem of combat-air capability against its most threatening potential state adversary is not one of insufficient platform capability – as is the case to a certain degree with France and Germany – but rather the inability to afford to operate sufficient mass to retain combat effectiveness in the face of attrition for any significant period of high-intensity combat operations.

Therefore, a crucial question for Team Tempest and the other elements of the Future Combat Air Strategy is whether it is preferable to either try and regain technological dominance over potential state opponents with an extremely ambitious design that would inevitably be very expensive, risky, and available only in small quantities, or to pursue a means of making currently cutting-edge signature-reduction and situational-awareness advantages more affordable, upgradable, and replaceable at reasonably short notice in order to reduce strategic vulnerability to combat losses. Given historical precedents, it seems imprudent for the UK to assume that it could afford to develop and field such a sufficiently technologically dominant system that attrition could be largely avoided. Therefore, like France, the next generation combat-air solution for the UK will need to provide some means of credibly shifting the bulk of anticipated combat losses in the event of high-intensity conflict away from both legacy and future manned airframes.

In terms of options for expendable capabilities beyond advanced decoys and cruise missiles, UCAVs offer one potential solution – whether in a manned–unmanned teaming configuration, or even as a potential fast-jet replacement. BAE Systems has already developed and test-flown the Taranis UCAV technology demonstrator, which was specifically designed to avoid dependence on US technology transfer, and which delivered a very-low-observable subsonic flying wing type aircraft for a modest total development cost of £185 million.[37] Unlike RPAS, such as the MQ-9 Reaper, which have come to symbolise 'drones' to the public, Taranis was designed to fly pre-programmed or dynamically tasked missions automatically if required, and does not need a human operator to remotely fly it, only supervise and direct the system when needed. Whilst Taranis has so far not been developed into a combat aircraft, the technology demonstrator does include internal bays for weapon or sensor payloads. Alongside nEUROn, Taranis is a potential source of design elements for any future Anglo-French UCAV as part of the FCAS programme, although Brexit and the Franco-German fighter announcement have made this less likely in the near term.

Nonetheless, a similar airframe with AESA radar arrays integrated into the leading edges of the wings could be a highly effective strike or airspace sanitation capability (bearing in mind legal and ethical constraints to do with direct real-time human remote control of weapons release and targeting decisions). Perhaps more importantly, such a UCAV could, if proven in prototype or

37. For more information on Taranis, see BAE Systems, 'Taranis', 2018, <https://www.baesystems.com/en/product/taranis>, accessed 1 September 2018.

through low-volume production runs, be maintained as a capability to be iteratively developed much more easily and cheaply than a manned fast jet. What a limited-size UCAV fleet would not be suited for, however, is conducting QRA duties in peacetime to intercept potentially hostile or highjacked aircraft near UK or NATO airspace. Nor is it likely, barring a major shift in public opinion and attitudes to lethal autonomous weapons, that the use of such a potentially politically sensitive capability would be authorised in a discretionary, low-threat conflict scenario. This suggests that at least some manned combat aircraft will remain an enduring requirement for the foreseeable future.

V. Sweden: The Scandinavian Wildcard

AS A CLOSE partner but not a member of NATO, Sweden has given more public consideration and planning importance to the potential dangers of a high-end conventional conflict with Russia than almost any other European country. In 2018, the Swedish government distributed a booklet to every household with advice on what to do in the event of a foreign military invasion and occupation, as well as in the case of other natural disasters, which includes instructions to never cease resistance even if seemingly ordered to do so.[38] With more than a century of armed neutrality behind it, the Swedish military is nonetheless a powerful force, albeit one with a very specific geographical and strategic focus on national defence. In terms of combat aircraft, Swedish manufacturer Saab has a history of producing superb, if unconventional, multi-role fast jets, from the double-delta-winged J-35 Draken and delta-canard AJ/JA-37 Viggen of the Cold War era, to the modern JAS-39 Gripen C/D. These unique aircraft were designed to be able to operate from stretches of remote highway to avoid dependence on vulnerable airbases. Although their pilots would of course be professionally trained, they are able to be serviced, refuelled, and rearmed by minimally trained conscripts without specialist tools and with turnaround times between sorties in the order of 10–20 minutes maximum.

In other words, Sweden has long operated combat-air platforms specifically designed not only to be lethal and survivable in the air, but also to minimise attrition on the ground in the event of a major conflict. As a side effect of being designed to be simple to maintain and service for troops with very limited training, the Gripen C/D as currently operated by the Swedish Air Force is also extremely cheap to operate compared to other NATO fast jets, and boasts impressive levels of reliability and sortie generation. Its small size also makes it somewhat harder to detect than larger aircraft with similar configurations. This means that even for a country with a very limited defence budget compared to the likes of the UK, France, Germany, or Italy, Sweden manages to maintain and operate a sizeable fleet of 97 Gripen C/D models, which will be slowly replaced by at least 60 of the new Gripen E by the mid-2020s.[39] Whilst this is still not sufficient to sustain large combat losses without significant degradation in combat capability, Sweden has accounted for this deficiency by moderating its defence level of ambition to territorial defence of its own airspace and territorial waters against Russian incursions, which should significantly reduce losses. With modern SAMs to help control Russian threats inside Swedish territory, an advanced dispersal plan involving buried hangars, the use of remote highways for sortie turnaround and extensive use of terrain masking and electronic warfare in flight, Sweden's

38. Swedish Civil Contingencies Agency, *If Crisis or War Comes* (Karlstad: Swedish Civil Contingencies Agency, 2018).
39. Gareth Jennings, 'Sweden to Upgrade MS20-Standard Gripen C/Ds', *Jane's International Defence Review*, 23 May 2018.

approach to its combat-air capabilities should make it more capable of sustaining operations in the face of its relevant high-end warfighting planning assumptions than those of most NATO members. The Gripen E attempts to build on this approach by doubling down on electronic warfare capabilities.

In much the same way as the US has designed its two fifth generation combat jets around minimising RCS whilst maximising situational awareness, the Swedish approach for its next generation Gripen variant is designed around blinding enemy sensors to the aircraft's presence, rather than trying to make the aircraft itself hard to detect. The Gripen E is designed around an internal EW suite, the capabilities of which are highly classified but are known to be optimised to frustrate the latest Russian long-range SAM and airborne scan and track radars.[40] The problem with using the Gripen family as a test case for relying heavily on the EW elements of a combat-air survivability mix is that it is almost impossible to know for certain how effective it would be in combat, without testing it in actual combat operations against Russian forces. EW suites rely on jamming signals and techniques which must be regularly updated and refined as the enemy alters their own radar frequencies, waveforms, and tactics – which would occur very quickly in actual combat operations. On the other hand, the advantage of EW over airframe shape-based stealth is that it can be regularly and relatively cheaply upgraded and updated in response to known threat developments.

Whilst Sweden has traditionally maintained a strongly independent ethos when developing its combat aircraft and, indeed, the vast majority of its military equipment, Gripen C/D and the next generation E model have benefited from significant industrial participation with NATO countries – in particular the UK. Furthermore, Saab participated with Dassault in the nEUROn UCAV technology demonstrator programme. Sweden might, therefore, be a potential partner in any future European combat-air programme, and one which could contribute significant expertise in electronic warfare, ease and efficiency of operation and maintenance, and advanced radar technology. However, its continuing policy of official neutrality and very defensive strategic focus might clash with the priorities of countries such as the UK and France which continue to place great value on power-projection capabilities at significant strategic distance. Furthermore, with at least 60 newly built Gripen E fighters ordered for delivery by the mid-2020s,[41] Sweden is unlikely to prioritise the development of another new combat-air solution in the next decade, meaning its timeframes for next generation procurement are out of step with the NATO combat-aircraft producing states.

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40. For public information on the Gripen E's EW approach, see Saab, 'The New Improved Electronic Warfare System of Gripen E', 24 April 2018, <https://saabgroup.com/media/stories/stories-listing/2018-04/the-new-improved-electronic-warfare-system-of-gripen-e/>, accessed 9 October 2018.
41. Saab, 'Gripen in the World: Users', <https://saab.com/gripen/our-fighters/users/>, accessed 9 October 2018.

VI. The United States: The Elephant in the Room

THE USAF REMAINS the most powerful and advanced in the world by a considerable margin, and even the air components of the maritime-focused US Navy (USN) and Marine Corps (USMC) are each larger and more powerful than any European air force. The US can also rely on funding for defence programmes almost unimaginable from a European perspective, has strategic depth with oceans and friendly states surrounding it, and has enormous reserves in terms of airframes, weaponry, and support infrastructure.

Nonetheless, the USAF, USN, and USMC all face significant obsolescence issues, with large numbers of aging fourth generation combat aircraft in many instances needing comprehensive mid-life upgrade programmes or urgent replacement. The fifth generation F-22 and F-35 are the most potent fighter aircraft in the world, but have cost far more and taken far longer to develop and manufacture than planned, which has led to the need to extend and upgrade older fleets to make up for the shortfalls – at significant cost. Almost two decades of near-continuous air campaigns as part of the War on Terror since 2001 have burnt through usable airframe life of legacy fleets and have also resulted in a serious decline in training and readiness for high-intensity warfighting against a peer opponent.[42]

Whilst the USAF, USN, and USMC all operate, or are poised to bring into service, the latest fifth generation tactical fighters, they are also struggling to afford to maintain and upgrade their legacy fleets, whilst simultaneously procuring the fifth generation F-35 in sufficient numbers to eventually replace the latter.[43] This makes it difficult to judge the prospects for follow-on fighters such as the USAF's F-X/PCA and USN's F/A-XX, both of which are loosely defined sixth generation concepts, given that replacing fourth generation fleets with fifth generation successors is unlikely to be completed before the 2030s at the earliest.

When discussing US requirements for future combat-air systems it is also important to remember that unlike European NATO members and partners, the Pentagon is more concerned in the long term about the state threat from China than from Russia. Russia is a declining (albeit heavily armed and unpredictably aggressive) power whilst China is on course to challenge the US as lead superpower in the next 20 years or so. This Indo-Pacific focus has implications for US next

42. For detailed information on declining high-intensity readiness in the USAF, see John Venable, 'Independent Capability Assessment of U.S. Air Force Reveals Readiness Level Below Carter Administration Hollow Force', report, Heritage Foundation, 17 April 2017.
43. Tyler Rogoway, 'Surprise, Surprise! The USAF Can't Afford its Fighter Fleet Past 2021', *The Warzone*, 23 May 2016, <http://www.thedrive.com/the-war-zone/3629/surprise-surprise-the-usaf-cant-afford-its-fighter-fleet-past-2021>, accessed 7 September 2018.

generation requirements. In particular, range on internal fuel will be a crucial driver due to the vast distances involved in Pacific operations, and the limited number and vulnerability of tankers, forward air bases, and (potentially) carrier groups to Chinese missile and aircraft threats. At the same time, the sheer size of the US tactical combat-aircraft inventory means that combat attrition is much less likely to be the dominant limiting factor in terms of maintaining combat effectiveness during a major conflict. Rather, it is more likely to be attrition of critical enablers, especially forward bases and tankers, which will limit effective US combat sorties during any high-intensity conflict in the Pacific. In a recent address, Air Force Secretary Heather Wilson announced plans over the next decade to grow the service from 312 to 386 squadrons to meet the threat of high-intensity conflict.[44] However, it is notable that within this very ambitious growth plan only seven of the new squadrons would be fighter squadrons, with the vast majority being for more enablers such as tankers, command and control, intelligence, surveillance and reconnaissance, and combat search and rescue.[45]

Part of the requirement for global reach beyond that which tactical fighters can provide is currently met by the trio of strategic bombers which the USAF operates: the venerable B-52 Stratofortress, supersonic B-1B Lancer, and stealthy B-2 Spirit. No other NATO members operate strategic bombers, but the USAF is already investing heavily in its next generation stealth bomber – the B-21 Raider. The B-21 will have conventional and nuclear delivery responsibilities and is being designed to be capable of penetrating deep inside heavily defended airspace at intercontinental ranges. Northrop Grumman was awarded the $80 billion contract in 2015 and the first aircraft are expected to be delivered to the USAF in the mid-2020s.[46]

The B-21 is unlikely to be purely a bomber in the conventional sense, with extensive surveillance, electronic-attack, and other multi-role capabilities expected to form part of the weapons system during the airframe's service life. The USAF has already announced a requirement for at least 100 B-21s, which is ambitious given that only 21 of the hugely successful but astronomically expensive B-2 Spirit were ever produced. However, there are many who believe that the US should procure far more than 100 airframes if the type proves successful in initial service, given its ability to carry very heavy payloads of both kinetic and non-kinetic varieties over vastly greater distances than tactical fighters without relying on vulnerable aerial-refuelling tankers and forward bases. In other words, if the B-21 programme proves successful, it could lead future US combat-air efforts away from the deep focus on tactical fighters which has defined airpower since at least the 1970s. For European partners, this would be difficult to follow, since none of them have designed or built a strategic bomber since the early 1960s. The tighter geography,

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44. Heather Wilson, keynote speech at the Air Force Association's Air, Space and Cyber Conference, National Harbor, MD, 17 September 2018.
45. Brian Everstine, 'USAF Plans Dramatic Increase in Number of Squadrons', *Air Force Magazine*, 17 September 2018.
46. Secretary of the Air Force Public Affairs, 'Air Force Selects Locations for B-21 Aircraft', 2 May 2018, <https://www.af.mil/News/Article-Display/Article/1510408/air-force-selects-locations-for-b-21-aircraft/>, accessed 7 September 2018.

greater airbase vulnerability, and airspace constraints of the European continent are less suited to a focus on large, scarce, high-value bombers.

Conspicuous by its absence is the lack of a publicly acknowledged UCAV-development programme by any of the US armed services. The Defense Advanced Research Projects Agency and Boeing's Phantom Works were proving the viability and promise of networked UCAVs with a high degree of in-flight autonomy through the X-45 programme as early as 2005, whilst Northrop Grumman developed the X-47B which by 2015 had demonstrated that UCAVs could both operate from aircraft carriers and conduct autonomous aerial refuelling.[47] Despite this, multiple subsequent programmes which aimed to deliver front line UCAVs to the USAF and USN, including the Joint Unmanned Combat Air System and the Unmanned Carrier-Launched Airborne Surveillance and Strike, have either been cancelled entirely or replaced with far less ambitious efforts to field unarmed survivable UAVs such as the surveillance-focused RQ-170 Sentinel and upcoming MQ-25 Stingray unmanned tanker. Put simply, the USAF and USN have both overtly turned their backs on pursuing UCAV capabilities which are demonstrably within the bounds of technological feasibility, and would offer significant advantages in high-intensity conflict scenarios. There are two explanations; either both services have decided that the potential benefits of UCAVs are not worth the potential threat which they represent to funding for advanced fourth and fifth generation manned fighter fleets, or the US has already developed combat capable UCAVs but has chosen to keep them secret and in relatively small numbers until they are really needed, to minimise the incentives for Russia and China to try to catch up. Both possibilities are problematic for other NATO partners seeking to optimise their own future combat-air capabilities without access to the 'black world' centred around the Tonopah Test Range in Nevada, since compatibility with future US force posture will remain a critical requirement.

Taken as a whole, the drivers for the next generation of US combat-air capabilities are very different from those of European NATO Allies. They are primarily based on the need to cover global commitments, often at great distances, whilst minimising dependence on and vulnerability of enablers such as tankers and forward bases. In terms of current force-posture deficiencies, platform capability and attrition tolerance are of less concern than affordability and procurement timelines for fifth generation fighters and the increasing costs and obsolescence issues facing the workhorse fourth generation fleets.

47. For a detailed examination of the USAF and USN's missing UCAVs, see Tyler Rogoway, 'The Alarming Case of the USAF's Mysteriously Missing Unmanned Combat Air Vehicles', *The Warzone*, 9 June 2016, <http://www.thedrive.com/the-war-zone/3889/the-alarming-case-of-the-usafs-mysteriously-missing-unmanned-combat-air-vehicles>, accessed 16 August 2018.

Conclusions: Implications for Next Generation Requirements and Characteristics

THERE ARE SEVERAL features of future high-intensity conflict which are likely to have major effects on capability drivers for next generation combat-air platforms and systems.

The first is the ever-increasing density, variety, and resolution of sensors on the ground and in the air, coupled with currently unimaginable computing power to conduct post-processing analysis on the data those sensors generate. This will make it harder to hide relatively large, high-speed, and high-temperature objects like aeroplanes in the cold, relatively empty, and transparent atmosphere. In the coming decades it may be extremely difficult or even impossible to approach and enter contested airspace completely undetected. The growth in the capability of coherent passive-radar systems which leverage reflected electromagnetic waves from background interference such as mobile phone, television, and Wi-Fi networks, as well as more traditional radio-frequency background noise to generate a radar-like track, will further expand this trend given the ever-increasing use of transmitting devices.[48] This predicted growth in situational awareness will most likely hold true for most high-end military actors, so Western air forces and militaries in general should know far more about what opposing forces are doing, as well as being more visible themselves, than is the case today. It will still be a great advantage to be hard to track and target, so stealth features will remain valuable – but other elements of the survivability equation such as speed, agility, electronic warfare, and mass may well regain some of their traditional importance.

The second feature is the proliferation of currently cutting-edge SAM systems and associated scan and tracking radars from Russia and China to countries which have hitherto been thought of as sub-peer opponents. This will greatly raise the risk and potential attrition costs of air operations which would currently be considered well below the threshold of high-intensity warfighting. Furthermore, the missiles of peer adversaries, and the multispectral sensors which cue and guide them from both ground and aerial platforms, will continue to grow more agile, long-ranged, and difficult to spoof with traditional defensive systems. China may also begin to export combat-air platforms which could directly rival Western capabilities to potentially hostile countries.

48. For detailed discussion of passive radar characteristics, limitations and potential future developments, see Hugh D Griffiths and Christopher J Baker, *An Introduction to Passive Radar* (Norwood, MA: Artech House Publishers, 2017), especially Chapter 6, 'Examples of Systems and Results' and Chapter 7, 'Future Developments and Applications'.

The third feature is that crucial enablers for combat aircraft such as large prepared airfields, aerial refuelling tankers, and the aviation fuel, spare parts, consumables, and munitions supplies on which sustained operations depend are likely to be held at threat by both kinetic and in some cases non-kinetic means much further away from the traditional battlespace than ever before. This is likely to be true to a lesser but still significant extent for aircraft carriers which will also be forced to operate significantly further away from hostile shores.

The question at the heart of this study is what these factors, and the individual situations facing each of the various Western-aligned combat-aircraft developing states, mean for the requirements for next generation combat aircraft within NATO.

The largest problem for non-US air forces in trying to prepare for high-intensity warfighting in the future will be the inability to negate the risks posed by significant combat attrition and inadequate combat mass through the pursuit of exquisite platform capabilities within limited budgets. Attrition would inevitably occur during high-intensity conflict whilst airborne as the result of SAMs and potentially aerial threats. But it will also occur on the ground at airbases, from diverse threats including cruise, ballistic and hypersonic missile strikes; deep-infiltration special operations forces; and swarms of micro-UAVs swamping point defences. Therefore, the next generation of combat-air systems must include a meaningful way of shifting the bulk of combat attrition away from the scarce manned platforms and their associated enablers, and onto assets which can be fielded in larger numbers and are ultimately expendable, require minimal currency training and public testing, and can be rapidly updated to suit new political and military circumstances.

One option might be to incorporate a series of technology demonstrators and low-volume production runs of UCAVs alongside the next generation of manned combat-air systems. Regularly updated UCAV prototypes and demonstrators offer the potential for iterative design flexibility as well as sensor- and weapons-fit options tailored more easily to evolving threat outlooks. One of the most important advantages of a UCAV over a manned or optionally manned combat aircraft is that no airframes are required to maintain the combat proficiency and flight currency of aircrew. Whilst it might be desirable to fly UCAVs during high-level exercises as well as occasional flights to check that individual airframe systems remain in good condition, most training for their use could be done synthetically. This would allow a combat force to be composed of far fewer airframes for a given front line strength than manned fast-jet fleets. Furthermore, small production batches would not have to be similar enough to each other to allow pilots trained on earlier variants to fly new ones, adding design and upgrade flexibility to a fleet throughout its life. In terms of increasing combat endurance for the force as a whole, UCAVs' design simplicity, expendability, and the lack of a requirement to train new aircrew means that increasing production during a crisis period and replacing combat losses to absorb attrition would be a much more feasible prospect than with manned systems – though it would still be expensive and industrially challenging.

Political requirements for future combat-air systems to secure full production funding may differ somewhat from the operational requirements against which such a system is initially designed.

The service lifespan of the fourth generation of combat aircraft has averaged around 40 years so far and the current stable of advanced fourth and incoming fifth generation fighters are expected to serve even longer. Therefore, political considerations about the risks of committing to a single 'shape' in terms of an airframe for an even longer potential service life are likely to make modularity, design flexibility, and upgrade potential ever more important as drivers of programme success. Due to the aerodynamically dependent aspects of flight control system design, and the shape-dependent nature of low-observability in various radar-frequency bands, this political desire for design flexibility will come into conflict with traditional aircraft development practices where a basic airframe shape and layout is identified as a first step, and then the rest of the programme designed on top. However, as already alluded to, a combat mix including some manned aircraft which would require an airframe to be chosen fairly early in development, but paired with an evolving stable of UCAV prototypes capable of fairly rapid production at scale if necessary, could give increased political flexibility. The small number of UCAVs available at any given time would be much cheaper to replace with upgraded airframe designs with different shapes and capabilities if the threat changes significantly than a single-type manned force.

The co-operative development of ideally a single but potentially even two different new manned combat aircraft by the UK, France, Germany, Italy, and Sweden with a relatively modest level of technological ambition is likely and seems broadly sensible. Comparable signature-reduction and sensor capabilities to the F-35 and F-22, but with simplified maintenance burdens and greater availability rates, might be achievable within cost and timeframe tolerances by the early 2030s if political priorities and timeframes can be aligned. However, this is unlikely to solve the outstanding problem that European air forces cannot afford to procure and operate sufficiently large fleets to allow them to credibly sustain long-term operations in the face of significant combat losses. On the other hand, this sort of manned replacement for Typhoon, Rafale, and potentially Gripen would provide enough employment and funding to maintain at least some indigenous combat-aircraft design-and-development capacity in those European countries.

Efforts to produce new manned combat aircraft would benefit greatly, however, from being coupled to a European UCAV programme to produce prototypes and low-volume production aircraft which could be tested, evaluated, and iteratively developed on a much shorter cycle than large manned combat-aircraft programmes. Without the need to train and keep pilots current, a UCAV force could be much smaller and cheaper than a manned fleet for a given front line strength. Politically, it ought to be easier to align the various national procurement cycles, budgets, operational requirements, and industrial workshare ambitions across the European countries discussed with a more flexible, evolving and low-volume production UCAV consortium than large-scale manned-fighter-fleet replacement efforts.

Whilst a relatively small, iteratively upgraded UCAV force would still be an expensive undertaking – reducing the funding available for a manned fleet – the latter could then be made less technologically ambitious, cheaper, and its smaller fleet size somewhat offset by additional UCAV combat mass. At the strategic level, the combination of such a potent latent capability alongside manned combat aircraft offers the potential for a greater and more sustainable deterrent effect against state opponents than an exquisite but nonetheless inevitably small and attritable force. At the same time, for out-of-area discretionary conflicts, and shows of presence, force, reassurance, and QRA as part of NATO, the more traditional manned fighter would still remain a valuable element of the future force – but one which could be shielded from the worst attrition in high-intensity scenarios by UCAVs.

About the Author

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