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Russian and Chinese Combat Air Trends

Current Capabilities and Future Threat Outlook

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Executive Summary

- The Soviet Union, and latterly Russia, have been the source of both aerial and ground-based pacing threats to Western airpower since the end of the Second World War. However, from a position of dependency on Russian aircraft and weapons, China has developed an advanced indigenous combat aircraft, sensor and weapons industry that is outstripping Russia's. As a result, for the first time since 1945, the likely source of the most significant aerial threats to Western air capabilities is shifting.
- Modern air combat is primarily decided by the balance of advantage in situational awareness. Given broadly comparable numbers, the force which can provide its aircrew with superior awareness of enemy position, track and identity will have a major advantage in any clash. In scenarios where situational awareness is relatively equal, missile reach and seeker performance, crew experience, aircraft performance, electronic warfare (EW) and countermeasures systems all contribute to the likely outcome.
- Russia and China currently field superficially similar combat aircraft fleets. Both rely heavily on the Su-27/30 'Flanker' family of combat aircraft and their various derivatives. They have also both pursued a fighter with low-observable (LO) – also known as stealthy – features, alongside increased multirole capability for their main fighter fleets. However, a clear Chinese lead is now emerging over Russia in most technical aspects of combat aircraft development.
- The Flanker family of combat aircraft share: a large radar, optical and heat signature; potent kinematic performance; a relatively long range on internal fuel; and the ability to carry heavy ordinance loads of air-to-air or air-to-ground weapons. This makes them comparatively easy to detect and, in the case of Russian Flanker types, the lack of a modern active electronically scanned array (AESA) radar restricts them to relatively 'brute force' tactics using powerful but easy-to-detect radars and missiles which are outranged by their Western counterparts.
- China has developed J-11 and J-16 series Flanker derivatives featuring AESA radars, new datalinks, improved EW systems and increased use of composites, which give them a superior level of overall combat capability to the latest Russian Flanker, the Su-35S.
- This advantage is increased by Chinese advances in both within-visual-range (WVR) and beyond-visual-range (BVR) air-to-air missiles. Unlike the latest Russian R-73M, the PL-10 features an imaging infrared seeker, improving resistance to countermeasures. More significantly, the PL-15 features a miniature AESA seeker head and outranges the US-made AIM-120C/D AMRAAM series. China is also testing a very-long-range air-to-air missile, known as PL-X or PL-17, which has a 400-km class range, multimode seeker and appears to have been designed to attack US big-wing ISTAR and tanker aircraft.
- China has developed and introduced into service the first credible non-US-made LO, or fifth-generation, fighter in the form of the J-20A 'Mighty Dragon'. Subsequent developments are likely to increase its LO characteristics and sensor capabilities, as well

as engine performance, with construction of the first production prototypes of the J-20B having begun in 2020.

- Overall, the Chinese People's Liberation Army Air Force (PLAAF) and People's Liberation Army Navy are rapidly improving their combat air capabilities, including a focus on the sensors, platforms, network connectivity and weapons needed to compete with the US in cutting-edge, predominantly passive-sensor air combat tactics.
- The Russian Su-57 Felon is assessed as not yet having matured into a credible frontline weapons system, and as lacking the basic design features required for true LO signature. However, it does offer the potential to correct many of the Flanker family weaknesses with greatly reduced signature and an AESA radar, while improving the already superb agility and performance of the Flanker series.
- The Russian Air Force (VKS) does not currently field targeting pods for its ground-attack and multirole fleets. This limits the ground-attack aircraft to internal equivalents with inferior field of view and tactical flexibility, and the multirole fighters to reliance on either pre-briefed GPS/GLONASS target coordinates, radar-guided weapons or target acquisition using fixed seekers on the weapons themselves. This limits VKS fixed-wing capabilities against dynamic battlefield targets compared to Western or Chinese equivalents.
- China is actively pursuing unmanned combat aerial vehicle (UCAV) designs with multiple programmes at various stages of development. Detailed assessment is hindered by tight control of information leaks by the Chinese Communist Party. Of those known to be in development, the GJ-11 subsonic attack UCAV appears the most advanced.
- Russia is also pursuing UCAV-style technologies and has produced the Su-70 'Okhotnik-B' technology demonstrator. However, it is not yet clear what degree of practical operational capability the Russian aircraft industry will be able to develop through the Su-70, especially given the demands for significant levels of in-flight autonomy inherent in UCAVs designed for state-on-state warfare in heavy EW conditions.
- China's advanced and efficient Flanker derivatives, as well as lightweight multirole fighters in the shape of the J-10B/C series and potentially a developmental FC-31 LO fighter programme, are likely to provide the leading source of non-Western combat aircraft from the mid-2020s onwards. Likewise, their air-launched munitions will increasingly outcompete Russian equivalents on the export market. As such, the development of Chinese capabilities should be closely monitored even by air forces which do not include the PLAAF in their direct threat assessments.
- The possibility of technology transfer from China to Russia in the combat air domain could potentially increase the threat level posed to NATO by Russian airpower in the longer term, should such a dynamic emerge.

Introduction

FAST JETS ARE only one aspect of modern aerial warfare, with ground-based integrated air defence systems (IADS) and big-wing enablers such as air-to-air refuelling tankers and ISTAR assets being crucial to the outcome of any real-world clash. Industrial factors, politically set rules of engagement, national budgets and risk tolerances also shape how each state can utilise combat aircraft in the long term and in individual scenarios. However, fast jets and the weapons they carry are the cutting edge of all combat-focused air forces. They are also generally developed with the most capable state-based threats in mind, even though, in practice, most will spend their service lives fulfilling much lower threat mission sets. Within this wider context, this report specifically examines fast jets and their weapons systems and capabilities.

Since the end of the Second World War, the Soviet Union, and latterly Russia, have been the primary source of aerial (and ground-based) pacing threats for Western air forces.[1] Today, Russia continues to develop, manufacture and export modern combat aircraft around the world. Over the past decade, China has evolved from a major customer and licensed (and sometimes unlicensed) manufacturer of Russian designs into a serious competitor on the global stage with several modern indigenous combat aircraft designs. Both must now be considered as the key sources of aerial pacing threats for NATO and Western-aligned air forces over the coming decades. Aside from the need to understand Russian and Chinese combat air capabilities from a great power deterrence perspective, both states offer their aircraft and weapons systems for sale on the global export market with few, if any, political strings attached. This means that while Western states having to directly face the Russian and Chinese air forces in high-intensity combat is a high-risk, low-probability scenario (although one which the US Air Force has been specifically directed to prepare for),[2] they will almost certainly face their aircraft and weapons systems being operated by sub- and near-peer competitor states.

This report follows on from, and is intended to complement, the author's previous research on modern Russian and Chinese integrated air defence systems.[3] Due to the sensitive nature of this topic, conducting fieldwork in Russia and China has not been possible, and the majority of

1. 'Pacing threat' is used to refer to the hostile capability development and deployment efforts which are making the most progress toward plausibly countering Western capabilities at any given point in time.
2. Department of Defense (DoD), 'Summary of the 2018 National Defense Strategy of the United States of America: Sharpening the American Military's Competitive Edge', <https://dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf>, accessed 30 September 2020.
3. Justin Bronk, 'Modern Russian and Chinese Integrated Air Defence Systems: The Nature of the Threat, Growth Trajectory and Western Options', *RUSI Occasional Papers* (January 2020).

the interviews with subject matter experts from the military, Defence Science and Technology Laboratory, think tanks and industry sector in the UK, the US and elsewhere could only be conducted remotely due to travel restrictions imposed by the coronavirus pandemic. The work of Piotr Butowski and Andreas Rupprecht on Russian and Chinese air capabilities respectively has also been particularly useful as a source of technical reference material drawn from Russian- and Chinese-language sources.[4] Although many of those interviewed have access to classified information, all discussions relating to this project were conducted at the open-source level. Thus, many of the more technical aspects of the subject, such as comparative radar or missile seeker performance, are necessarily discussed in relatively broad terms.

Chapter I provides a basic guide to the interactions which govern modern air-to-air combat, since an understanding of these is essential for evaluating Russian and Chinese capabilities in relation to their Western equivalents. Chapter II examines the current generation of Russian combat aircraft, and the more significant development programmes, while Chapter III deals with Chinese indigenous designs and development of advanced derivatives of Russian airframes. The conclusion places Russian and Chinese combat air capabilities and development programmes within their respective national military strategies, and analyses the potential implications for Western air forces.

4. For example, Piotr Butowski, *Flashpoint Russia: Russia's Air Power: Capabilities and Structure* (Czech Republic: Harpia Publishing, 2019); Andreas Rupprecht, *Modern Chinese Warplanes: Chinese Air Force – Combat Aircraft and Units* (Czech Republic: Harpia Publishing, 2018).

I. Modern Air Combat

THIS CHAPTER EXAMINES the main factors which govern modern air combat. Air combat is an extremely dynamic and context-dependent activity, and there will always be scenarios which may be decided by a different balance of factors to the one outlined here. It is also very unusual for two air forces to confront one another on broadly equal terms; one side typically has advantages in terms of numbers, training, whole force enablers and mission objectives driving their behaviour. Nevertheless, this chapter is intended to provide a working understanding of the dominant factors at play between opposing fighter forces at the tactical level in a hypothetically symmetrical meeting.

Situational Awareness

Air combat has always been first and foremost a contest of situational awareness. It is also fundamentally a team activity, with the smallest tactical formation being a pair (of aircraft), but 'four-ship' formations operating as part of larger complex air operations being the norm. The side which can locate and identify the other first has a huge advantage: being able to manoeuvre to either avoid or initiate a subsequent combat engagement under the best possible circumstances. During the First and Second World Wars, this was predominantly decided by a combination of pilot eyesight, formation tactics and – later – the information from ground-based radar stations provided verbally over radios by ground controllers. From the Vietnam War to the present day, by contrast, airborne (and ground-based) radar has overtaken the human eye as the primary sensor for building fighter pilots' situational awareness. Modern missiles are vastly more capable than those of the Vietnam War, offering long ranges, impressive agility and sophisticated seeker heads. This means that the pilot who gets the first look, and therefore the first shot off, is also likely to kill their opponent. Pilot training and experience levels are, of course, crucial since situational awareness is a measure of how successfully a pilot can take information presented to them by the aircraft, radio communications and their own eyes, and interpret that information to generate an accurate mental picture of the airspace around them. This situational awareness building must be done while flying a complex machine at high speeds as part of a larger formation, often under heavy G-loads.[5] However, assuming

5. Rapid changes of direction at high speeds cause significant increases in felt gravitational forces acting on aircraft, weapons and crew during manoeuvres due to changes in relative acceleration. The measurement for these forces is 'G', with 1G being equal to normal gravitational acceleration as experienced standing on Earth. Fast jet pilots are equipped with 'G-suits' which constrain the flow of blood to the legs and feet via automatic inflation and deflation, helping to keep the brain from being starved of oxygen during high-G manoeuvres, and allowing them to operate at up to 9G for limited periods with proper training. Modern fighter aircraft are generally stress tested and cleared for flight loads of up to 9G in air combat configurations, as this is recognised as the physiological limit for pilots.

semi-equivalent pilot skill and capacity levels, sensors are crucial determinates for situational awareness levels in modern air combat. In pursuit of that first look, modern fast jets generally carry a powerful forward-facing radar in the nose, as well as datalinks to exchange data with ground- and air-based wide-area surveillance assets and other fast jets.

Radars can be designed to operate in various bands of the radar spectrum, from the high-/very-high-frequency (HF/VHF) decimetre/metre wavelength band up to millimetric wavelengths.[6] Generally speaking, longer wavelengths allow greater ranges at the cost of resolution/accuracy of track for a given radar antenna size. Technically, the angular accuracy and resolution is determined by the ratio of wavelength to antenna size.[7] Fast jet radars are typically designed to operate within the X and Ku bands of the spectrum, as this gives the best balance of long-range performance and resolution (track fidelity) within the size and power constraints of a fighter aircraft's nose.[8] However, ground-based early warning and surface-to-air missile system (SAM) radars can also exploit other parts of the spectrum, since they can use larger and differently shaped antennas and draw on greater power and coolant sources. All modern combat aircraft are also equipped with passive antenna sensors called 'radar warning receivers' (RWRs), which tell a pilot which external radars are emitting energy within range of detection, and whether any of those radars are locked onto their aircraft and/or guiding a missile towards them. Radars require energy emitted to travel to a target, reflect back and be received by the antenna in order to detect it. In contrast, that energy only has to reach a hostile asset to be detected, so a radar which is actively scanning will generally be detectable by hostile forces at a greater range than it can detect targets. The radar mounted in the nose of a fighter aircraft can also only scan in a cone ahead of the aircraft. An analogy is that a fast jet radar is like having a narrow beam torch in a dark room – it illuminates whatever it is pointed at well, but also exposes the user's location to anyone else in the room and does not show the big picture. By contrast, the wide-area surveillance radars used by airborne warning and control system (AWACS) aircraft like NATO's E-3 Sentry, Russia's A-50 Mainstay and China's KJ-2000 provide one side with the equivalent of a ceiling-mounted light, showing the entire battlespace.

The desire to be able to detect and attack targets without alerting hostile forces to the presence of one's own aircraft has led to the development of three major areas of sensor technology and techniques. The first is greatly improved electronic support measures (ESM), an overarching term for passive detection, identification and tracking capabilities that rely on intercepting hostile energy emissions using RWRs and main radar antennas on receive-only. The second is the development of passive scanning sensors, most notably infrared scan and track (IRST) and electro-optical (EO) sensors, which search for heat signatures and recognisable shapes

6. Despite standing for 'high frequency', the HF (decimetre/metre wavelength) is actually the lowest frequency part of the radar spectrum. As wavelengths decrease, frequency increases.
7. For a more detailed overview, see radartutorial.eu, 'Waves and Frequency Ranges', <https://www.radartutorial.eu/07.waves/Waves%20and%20Frequency%20Ranges.en.html>, accessed 12 June 2020.
8. Christian Wolff, 'Radartutorial: Book 2 "Radar Sets"', p. 11, <https://www.richardsonrfpd.com/docs/rfpd/Radar_Tutorial_Book2.pdf>, accessed 30 July 2020.

within the infrared and visible light bands of the electromagnetic spectrum. These systems have significantly shorter ranges than radar, and are affected by adverse weather and atmospheric conditions, but they emit no tell-tale energy that an opponent can pick up. The third major area of sensor development has been the development of active electronically scanned array (AESA) radars. These radar sets generate hundreds of small, digitally steered beams of energy to scan for and track targets instead of one large mechanically steered beam.[9] This has several advantages, including the ability to constantly vary the frequency, wavelength and pulse frequency being used for each beam, which makes detecting an AESA radar's emissions much harder than for a mechanically scanned traditional array. This capability to actively scan for targets with minimal chances of alerting them is called 'low probability of intercept/low probability of detection' (LPI/LPD) and confers huge situational awareness advantages over opponents relying on traditional mechanically scanned radars. In other words, LPI/LPD capabilities allow the metaphorical flashlight user in the dark room to use a beam which only they can see. AESA radars also offer the capability to simultaneously perform air-to-air and air-to-ground scans, improved range, resolution, resistance to jamming and number of targets that can be tracked at once compared to older radar types.

In addition to advanced sensors to try and detect hostile threats at the longest distance and with the greatest possible resolution, many modern fast jets also incorporate measures designed to make them more difficult for hostile forces to detect. Most notably, these include airframe shaping techniques and coatings designed to reduce the amount of incoming radar energy reflected back by the jet towards a hostile radar. These stealth technologies do not make an aircraft invisible to radar but can decrease the range at which a given hostile radar is likely to detect it by several orders of magnitude. The aim is to allow combat aircraft to destroy or avoid aerial and ground-based threats and complete their missions without being detected, or at least without being reliably tracked. The effective radar cross section (RCS) of an aircraft will depend on which aspect it is being viewed from, as well as what band of the radar spectrum and what signal processing techniques are being used to try and detect it.

Different shapes are optimal for reducing RCS in different bands of the spectrum, and the overall aircraft shape must still generate aerodynamic lift and controllability in flight. Therefore, every stealth aircraft design is a compromise between aerodynamic qualities and RCS optimisation from various aspects in as much of the radar spectrum as possible. The starting point for stealth designs is to minimise RCS when viewed head on, and in the X and Ku bands used by most fire control radars. External fuel tanks and weapons are a major source of radar reflections on any aircraft, so stealth aircraft must carry their fuel and weapons in internal bays, making the overall aircraft more complex and shorter ranged than it would otherwise be for a given size and weight. In terms of degrees of stealth, the often-used descriptions of low observable (LO) or very low observable (VLO) are somewhat subjective; many modern fighters incorporate LO design features to reduce frontal RCS, but only very specialised designs like the American F-22

9. For more information, see US Naval Academy, Weapons and Systems Engineering Department, 'Fundamentals of Naval Weapons Systems', chap. 7, <https://fas.org/man/dod-101/navy/docs/fun/index.html>, accessed 16 June 2020.

Raptor, F-35 Lightning II and B-2 Spirit, which were developed from the outset with so-called ‘all-aspect stealth’ (minimal RCS from all angles), can be considered VLO.

For a fast jet designed to be LO or VLO, an AESA radar with advanced LPI/LPD and advanced ESM capabilities are just as vital as airframe shaping and radar-absorbent coatings since they must be able to build situational awareness and employ radar-guided weapons successfully without being detected via their own radar emissions. The modern combat air environment is characterised by a wide variety of fast jets with modern sensors, datalinks and weaponry, but only a few VLO, AESA-equipped types. The latter have an overwhelming advantage in being very difficult to detect on radar and able to scan for and attack targets with little risk of being located as a result of their own sensor emissions. In other words, mature VLO combat aircraft enable pilots to deny situational awareness to the enemy while building it very effectively and covertly themselves. After situational awareness, other important factors include weapons effectiveness and range/endurance on station.

Weapons

Weapons carriage capacity, and the probability of kill (P_k) for those weapons against the targets in question, determines the number of targets that can be successfully attacked or defeated in a given sortie. P_k varies depending on: the range between the launch aircraft and the target; the speed and altitude of the launch aircraft compared to the target; the aspect of the target (is it flying towards, at a right angle to or away from the launch aircraft?); the capabilities of the missile itself; and the countermeasures likely to be employed by the target after launch. Traditional missiles are powered by a solid-fuel rocket motor which rapidly accelerates the missile to several times the speed of sound in a burn phase, lasting for several seconds after it has been launched from an aircraft. Once the motor has burnt out, the missile glides towards a predicted intercept point with the target aircraft and, in its terminal phase, attempts to manoeuvre to hit it using the remaining kinetic energy imparted to it at launch and during the initial burn. If a target is flying directly away from the launch platform, a given missile will have to be fired from much closer to that target, because it has to catch up with it, while retaining sufficient energy to successfully manoeuvre to hit or explode next to it. Likewise, if a target is flying directly towards the launch aircraft, then a missile can theoretically hit it when launched from much farther away. The no-escape zone (NEZ) is a term for the volume of space within which the missile has enough kinetic energy to intercept the target, irrespective of any evasive manoeuvre the target aircraft executes after launch. Once within the NEZ, P_k for any missile against a given target will increase significantly.

There are three main types of air-to-air missiles which differ according to what kind of seeker head is used to guide them to their targets. The first are IR or imaging IR (I2R) ‘heat seekers’ which are passive and attempt to acquire and then home in on the heat generated by target aircrafts’ engines and airframes as they are heated by friction at high speeds. Russia and France both field beyond-visual-range (BVR) IR homing missiles in the shape of the R-27T/ET (also known by its NATO reporting name, AA-10 Alamo-B/D) and Mica (I2R) respectively.[10] However, IR missiles are mostly used for within-visual-range (WVR) engagements during air combat manoeuvres (ACM) – otherwise known as 'dogfighting'. Modern IR missiles are extremely agile, capable of turns of up to 50 g, and are usually aimed with helmet-mounted sights which enable pilots to designate targets well off boresight simply by looking at them. Some also have multi-band seekers which are sensitive to the ultraviolet (UV) band of the spectrum to increase their ability to discriminate between the actual target and decoy flares. The most modern I2R missiles include imaging seekers which are sensitive to the expected shape of a target aircraft as well as the heat signature, making them much more resistant to being spoofed by flare decoys. They are also able to lock on to VLO targets which would be difficult for radar-guided missiles to acquire. Some are also capable of lock-on-after-launch engagements which allows them to be used for targets not directly in view of the seeker when fired, including directly behind the launch aircraft. These missiles make WVR engagements exceptionally deadly for all combat aircraft.

The second class of air-to-air missiles are semi-active radar-guided weapons. These weapons are passive and require a target to be locked and illuminated in either single-target-track (STT) or track-while-scan (TWS) modes by the launch aircraft's radar, so that the missile seeker can home in on the radar energy which is then reflecting back off the target.[11] As such, semi-active radar missiles require the launch aircraft to maintain an active radar lock on the target aircraft throughout the engagement. If that lock is broken by manoeuvring, counter attack or jamming, the missile will fail to hit its target. To partially alleviate this vulnerability, some modernised semi-active missiles have been equipped with mid-course datalinks to allow periodic target position updates in flight even if full radar illumination of the target has been lost. However, such updates will only help the missile stay roughly on course – full illumination is still required

10. *Air Force Technology*, 'R-27 (AA-10 Alamo) Guided Medium Range Air-to-Air Missile', <https://www.airforce-technology.com/projects/r-27-aa-10-alamo-guided-medium-range-air-missile/>, accessed 15 June 2020; *Air Force Technology*, 'MICA Air-to-Air Missile System', <https://www.airforce-technology.com/projects/mica-air-to-air-missile-system/>, accessed 16 June 2020.
11. Single target track (STT) involves the launch aircraft focusing all its radar energy in a narrow cone centred on a single target in order to give the highest fidelity tracking solution, potentially detect identification features and provide a strong source of reflected energy for a missile to home in on. However, STT prevents the launch aircraft from scanning for other targets during an engagement, and the concentrated radar energy will tell a RWR-equipped adversary that they are being locked up. Track while scan (TWS) is a more advanced technique where only some of the available radar energy is directed to locking a target, resulting in lower resolution and less precise information about the target being generated, but allowing some scanning for other targets during an engagement, as well as the option of guiding multiple weapons to different targets simultaneously. An aircraft being attacked in TWS mode may not receive a RWR indication that they are being launched on, although they will still be able to detect the radar signal from the attacking aircraft unless it is using an LPI/LPD capable radar. For more information, see US Naval Academy, Weapons and Systems Engineering Department, 'Fundamentals of Naval Weapons Systems', chaps 6 and 7.

for the terminal interception phase.[12] These missiles are now relatively uncommon among modern air forces, with Russia's R-27R/ER (AA-10 Alamo-A/C) and the American AIM-7 Sparrow remaining in limited service around the world but being phased out.[13] One other Soviet-era development of the semi-active missile category was the fully passive seeker missile which was designed to home in on energy emitted by enemy radar or EW – the R-27P/EP (AA-10 Alamo-E/F). These missiles have generally been retired from frontline service.[14]

The final and most important category is active radar-guided missiles.[15] These carry their own active radar which is able to acquire and home in on targets during the terminal phases of flight without relying on reflected energy from the launch fighter's radar. This means that once the missile has 'gone active' and acquired the target for itself, the fighter which launched it can turn away to evade counter-fire and/or maintain distance with the target, return to passive sensor mode only to reduce electromagnetic visibility, or concentrate fully on attacking other targets. Active radar-guided missiles can also be fired in fully autonomous search and destroy mode in emergencies, although this would be a rare occurrence given the danger of the missile acquiring and destroying friendly aircraft or other unintended targets, as well as a much lower P_k in general. Active radar-guided missiles which feature datalinks can be fired without the launch platform using its active radar at all, if it is aware of the target's location, identity and course from passive or offboard sensors. In such a case, the first warning that the target aircraft might have that it has been launched on would be the missile 'going active' around 7–10 seconds before impact. The American AIM-120 AMRAAM, Anglo–French Meteor, Russian R-77-1 (also known by its NATO reporting name, AA-12 Adder) and Chinese PL-12 and PL-15 are examples of modern active radar-guided missiles.[16]

Both active and some semi-active radar-guided missiles also feature secondary 'home on jam' capabilities, whereby the missile attempts to acquire and home in on the energy being emitted by a target's electronic countermeasures (jamming signal) rather than reflections from the

12. For more detail, see US Naval Academy, Weapons and Systems Engineering Department, 'Fundamentals of Naval Weapons Systems', chap. 15; Carlo Kopp, 'Active and Semiactive Radar Missile Guidance', Air Power Australia, originally published in June 1982, last updated in 2005, <http://ausairpower.net/TE-Radar-AAMs.html>, accessed 17 June 2020.
13. For a detailed overview of the AIM-7 Sparrow, see Military-Today.com, 'AIM-7 Sparrow', <http://www.military-today.com/missiles/aim_7_sparrow.htm>, accessed 17 June 2020. For details on the R-27 series, see *Air Force Technology*, 'R-27 (AA-10 Alamo) Guided Medium Range Air-To-Air Missile'.
14. Author correspondence with Douglas Barrie, Senior Fellow for Military Aerospace, International Institute for Strategic Studies (IISS), August 2020.
15. NATO, 'Joint Brevity Words Publication, APP-7(E)', 2009, p. 25, <http://nato.radioscanner.ru/files/article140/brevity_words_app7e_.pdf>, accessed 15 June 2020.
16. For discussions on the Meteor and AIM-120D, see Tyler Rogoway, 'Is the European Meteor Air-to-Air Missile Really the Best in the World?', *The Warzone*, 2 August 2016. On the R-77-1, see Douglas Barrie, 'Russia's *Foxhound* Finally Gets Its Bite Back', Military Balance blog, IISS, 30 April 2019, <https://www.iiss.org/blogs/military-balance/2019/05/russia-foxhound-upgrades>, accessed 17 June 2020. On the PL-15, see Rupprecht, *Modern Chinese Warplanes*, p. 111.

launch aircraft's radar.[17] A similar concept is the anti-radiation missile seeker, which is designed to home in on the energy being emitted by enemy radar systems – such weapons are employed against both airborne and ground-based radar threats.[18]

Combat aircraft employ various techniques to try and defeat attacks by these various types of missiles once they have been launched. The simplest technique is to defeat an incoming missile through manoeuvring the aircraft such that either the missile cannot reach it with the energy it has remaining, or the missile seeker cannot acquire the target or loses a lock that it already has. If a missile is fired from outside its NEZ, such a manoeuvre can be as simple as turning around and flying in the opposite direction from the attacking aircraft – leaving the missile with insufficient energy to catch up. Alternatively, rapid changes in heading and/or altitude – especially at high speeds – can force incoming missiles to make sharp, energy-sapping turns to maintain an intercept course for the point where it and the target's predicted flight paths meet. Since most missiles gain their energy from the launch aircraft's speed and altitude at launch, plus their initial rocket burn, forcing a missile to make rapid changes in heading and altitude after its motor burn has finished can rapidly deplete its energy below that of the target aircraft, which has constant power from its engines. Modern missiles have improved predictive algorithms and can receive mid-course guidance via datalinks from the launch aircraft (or other friendly aircraft) which make them less susceptible to such tactics, but they remain a core part of fighter pilot training and tactics nonetheless.[19] If a missile is fired from within its NEZ, then manoeuvres alone are far less likely to defeat it before impact.

Almost all modern fighter aircraft are still equipped with a rapid-firing internal cannon for close-range engagements during ACM as a last resort, as well as for ground-strafing purposes. In a dogfight, the fighter's primary radar can be locked onto a hostile aircraft to provide the internal systems with accurate target range, speed and angle information, allowing the computer to present the pilot with a precise aiming cue to hit high deflection shots at high speeds. While limited to attacking targets directly ahead of an aircraft and at very close ranges, cannon do retain advantages over missiles in such situations, being completely unaffected by decoys, VLO features or electronic countermeasures.

Countermeasures and Fuel

Decoy countermeasures are carried by almost all combat aircraft for use in conjunction with defensive manoeuvres. Flares are a long-established tool for use against IR missiles. They are released in salvos to try and entice the seeker head away from the target aircraft with a large number of other very hot objects. However, modern I2R and multi-spectral seeker heads are specifically designed to be highly resistant to flare decoys. Against semi-active and active radar seeker missiles, chaff decoys are used in a similar way. Chaff generates small bursts of

17. US Naval Academy, Weapons and Systems Engineering Department, 'Fundamentals of Naval Weapons Systems', chap. 11, section 2.2.7.
18. *Ibid.*
19. Author interviews with US Air Force pilots, RAF Lakenheath, 20 May 2019.

radar-reflective material to try and spoof the missile seeker head into chasing a reflective target other than the aircraft itself. Some aircraft also carry towed decoys which, upon release, trail on a cable and emit signals designed to mimic the radar reflections from a full-sized aircraft to entice incoming missiles to hit them instead.[20] Electronic countermeasures (ECM) (also known as jamming) suites are also a standard feature of modern combat aircraft. ECM suites can degrade hostile radars, disrupt semi-active and active radar-guided missile seeker heads and/or datalinks between hostile missiles and the launch vehicles. They do this by emitting their own signals to either drown out all other signals within a given frequency band (noise jamming) or emitting specific counter-signals in the direction of a particular threat.[21] One of the most modern techniques is digital radio frequency memory (DRFM) jamming, where receivers detect and record the radar waveform being used to guide an incoming missile and then an antenna retransmits that same signal, with the pulse timing tweaked to mislead the missile away from its target.[22] These various defensive techniques are often used in combination.

The most sophisticated combat aircraft in the world will still fall out of the sky when its fuel runs out. Combat radius is a measure of how far from an airbase or air-to-air refuelling tanker orbit a combat aircraft can fly before having to return to base (or back to the tanker). This is affected by the type of mission, since certain tasks require more time 'on station' once in the combat area, and fuel efficiency improves dramatically for mission profiles flown at high altitudes compared to those flown low down. Furthermore, if supersonic flight or ACM using afterburners (where raw fuel is sprayed into the hot jet exhaust for significantly increased thrust at the cost of much higher fuel consumption) are required, this will significantly reduce combat radius. Some modern fighter aircraft are designed to be able to supercruise – that is, fly faster than the speed of sound without using afterburners. This allows them to impart more energy to their missiles at launch and cover large distances quickly without the huge fuel consumption penalty of using afterburners. However, supercruising is typically only possible without large external fuel and weapon loads, and still results in significantly higher fuel consumption than subsonic cruise.

In summary, modern air combat is determined first and foremost by which side is able to generate and sustain superior situational awareness over the other. This is governed by a combination of superior sensors, signature minimisation (stealth and emission control techniques), datalink-enabled sharing of information between different assets, in-cockpit interfaces and crew proficiency. A situational awareness advantage will allow one side to position assets and then manoeuvre so as to begin and conduct an engagement on the most favourable terms, and at least to get the first shots of an engagement. If both sides have relatively comparable situational

20. See, for example, Leonardo, 'Fibre Optic Towed RF Decoy', 2017, <https://www.leonardocompany.com/documents/20142/3149276/Ariel_LQ_mm07735_.pdf?t=1538987424584>, accessed 23 July 2020.
21. US Naval Academy, Weapons and Systems Engineering Department, 'Fundamentals of Naval Weapons Systems', chap. 11.
22. See, for example, John Keller, 'Navy and Air Force Choose DRFM Jammers from Mercury Systems to Help Spoof Enemy Radar', *Military & Aerospace Electronics*, 18 June 2014, <https://www.militaryaerospace.com/trusted-computing/article/16718948/navy-and-air-force-choose-drfm-jammers-from-mercury-systems-to-help-spoof-enemy-radar>, accessed 16 June 2020.

awareness about the other’s position, identity and heading prior to getting within missile range, then the side with superior effective missile range has a significant advantage. This is both a matter of missile range in technical terms, and also aircraft performance since the faster, higher-flying fighter will be able to get the first shot off, given equivalent missiles, by imparting more energy at launch. The long range and high countermeasure resistance of modern missiles means that the side which is fired on first is likely to remain on the defensive until they withdraw or are destroyed. If a pilot detects an incoming missile, the evasive manoeuvres required to try and defeat it will cost energy and altitude, and may force them to go ‘nose cold’ which entails turning their primary sensors away from the enemy threat. All the while, the aircraft which fired first can monitor the progress of the engagement while conserving an energy advantage and can fire additional missiles if an initial hit appears unlikely. High levels of aircraft acceleration and good energy retention capabilities help minimise energy losses during offensive and defensive manoeuvres and if afterburner reliance can be minimised during such manoeuvres, combat persistence in prolonged engagements will be greatly improved.

The factors above deal primarily with BVR combat. In WVR combat, there is little to choose between high-end modern combat aircraft since most are capable of pulling and sustaining 9G – the limit for human pilot endurance even with specialised G-suits – and are armed with extremely agile, countermeasure-resistant imaging IR missiles cued in by helmet-mounted sights. In other words, within visual range during a ‘merge’, both sides are so lethal that most combats will be over extremely quickly – before subtle differences in sustained turning performance or energy retention make a major difference.

II. Russian Fast Jet Capabilities

AS OF THE end of 2018, the Russian Aerospace Forces (VKS) maintained an active service inventory of 795 fast jet aircraft alongside 126 heavy bomber aircraft, while the Naval Aviation of the Navy (MA VMF) operated a further 126 fast jets.[23] In addition, one to two low-rate initial production Su-57 LO fighter aircraft have been accepted by the VKS since 2018, with the type participating in short test deployments to Syria in 2018 and 2019.[24] The VKS also operates a fleet of nine A-50M Mainstay AWACS aircraft, and 15 Il-76 tankers which predominantly support heavy bomber operations.[25] Table 1 includes a breakdown of the major types which make up this large fleet.

Table 1: Combat-Capable VKS and MA VMF Fast Jet Types as of Late 2018

Fleet Size	Type	Role
98	Mig-29SMT/KR/KUBR ‘Fulcrum-F’	Medium/carrier multirole fighter
139	Mig-31BM/BSM/BP(K) ‘Foxhound’	Interceptor/ballistic missile launch platform
100	Su-24M ‘Fencer-D’	Strike/anti-ship bomber
140	Su-25SM ‘Frogfoot’	Ground attack
115	Su-34 ‘Fullback’	Multirole strike fighter bomber
333	Su-27SM/Su-30M2/Su-30SM/Su-35S ‘Flanker F/C/E’	Heavy multirole fighter
14	Su-33 ‘Flanker-D’	Carrier fighter
1–2	Su-57 ‘Felon’	Developmental low-observable fighter

Sources: Piotr Butowski, Flashpoint Russia: Russia’s Air Power: Capabilities and Structure *(Czech Republic: Harpia Publishing, 2019), pp. 141–42; IISS,* The Military Balance 2020 *(London: IISS, 2020), pp. 199–201.*

Note: These totals are the author’s best estimates based on the sources available and exclude non-combat coded aircraft assigned to training or operational test and evaluation units.

23. Butowski, *Flashpoint Russia*, pp. 141–42.
24. Roger McDermott, ‘Moscow Plans Additional Modifications to Its Fifth-Generation Su-57 Fighter’, *Eurasia Daily Monitor* (Vol. 17, No. 71, May 2020). See also Joseph Trevithick, ‘Russia Releases First Official Video of Its Su-57s on Their Absurdly Short Trip to Syria’, *The Warzone*, 19 November 2018.
25. IISS, *The Military Balance 2020* (London: IISS, 2020), p. 201.

Russian Air-to-Air Weapons

Russia's air-to-air weapons development suffered badly during the years after the fall of the Soviet Union, with multiple projects cancelled or permanently shelved. Most Russian combat air sorties are still flown with the same R-73 (AA-11 Archer) short-range and medium-range R-27 (AA-10 Alamo) variants that were common in the 1980s. The R-74M is an upgraded variant of the R-73 with slightly better kinematics but still without a modern imaging IR/UV seeker head like those found on many American, European and Chinese rivals.[26] The R-27ER and ET (Alamo-C/D) (extended range, semi-active radar-guided, and extended range, IR-guided) are in a roughly similar range class as the AIM-120B, with slightly higher energy loss at longer distances due to larger fins. The R-77 (AA-12 Adder) was intended to replace the R-27R/ER (Alamo) series as Russia's active radar-guided equivalent to the American AIM-120 family. However, its development was slowed by the fall of the Soviet Union and it never entered service with the VKS – being predominantly an export product.[27] The R-77-1 variant was introduced in 2010 for limited VKS service with upgraded seeker performance, better streamlining to reduce energy loss at longer ranges and improved carriage life.[28] Its performance at longer ranges is inferior to the AIM-120C series of the AMRAAM due to the agility-enhancing but higher drag lattice fin arrangement which was chosen for the R-77 and R-77-1. A variant called the K-77M (AA-X-12C Adder) with conventional fins and a more potent dual-pulse motor is being developed for internal carriage by the Su-57 Felon, with performance claimed to be comparable to the AIM-120C7.[29] No K-77M has been seen in public footage or photographs, and the status of the project is unclear.

There are also rumours of a ramjet-powered variant of the K-77M intended to compete with the MBDA Meteor missile, but there have been no orders for this project yet.[30] As such, conventional Russian radar-guided missiles in service with the VKS remain significantly outranged by their equivalents in NATO states – the AIM-120C7/D and Meteor.

In terms of very-long-range missiles, the huge R-37M (AA-13 Axehead) can more or less match the Meteor and exceed the AIM-120C/D in terms of range when fired from its primary launch platform, the Mig-31BM high-altitude interceptor.[31] The R-37M is a much larger, heavier and more expensive missile than the R-27 (Alamo) or R-77 (Adder) series. While it can theoretically be carried on Flanker-series aircraft, the weight and drag penalty would be extensive, and limited

26. Douglas Barrie, 'Chinese and Russian Air-Launched Weapons: A Test for Western Air Dominance', in *Ibid.*, pp. 7–9.
27. *Ibid.*
28. Piotr Butowski, *Russia's Air-Launched Weapons: Russian-Made Aircraft Ordnance Today* (Czech Republic: Harpia Publishing, 2017), pp. 51–52.
29. *Ibid.*, pp. 52–53.
30. See, for example, Tom Cooper, 'Russia's Most Feared Air-to-Air Missile Is Actually Kind of a Dud', *War is Boring*, 14 November 2016, <https://medium.com/war-is-boring/russias-most-feared-air-to-air-missile-is-actually-kind-of-a-dud-ebebe8b28f4f>, accessed 30 July 2020.
31. Butowski, *Russia's Air-Launched Weapons*, pp. 55–56.

stocks coupled with the core anti-cruise-missile role of the Mig-31BM fleet mean that the R-37M is unlikely to see regular service on other Russian combat jets. Russian missile manufacturer Vympel won a contract to develop a very-long-range (300 km+) missile called Izdelie 810, suitable for internal carriage on the Su-57 in 2009.[32] However, so far no confirmation has been seen that the missile progressed beyond the developmental stage, and more recently Russian media has suggested that either the R-37M or a derivative of a ground-based SAM called the K-100 might be used instead.[33] On the other hand, Western experts suggest the K-100 has been cancelled.[34] The R-37M would have to be externally carried by Su-57 (greatly increasing the RCS of the aircraft) since, in its current form, it would not fit into the central weapon bays.[35] Therefore, it seems reasonable to conclude that the Su-57 (and all other Russian tactical fighters) currently lack a practical very-long-range missile capability and remain outranged by their Western (and Chinese) competitors, which is a major disadvantage in modern air combat.

Flankers

The core of Russia's active fast jet fleet consists of the 333 Sukhoi Su-27/30/33/35 'Flanker' family of air superiority and multirole fighter variants. The Flanker series has represented the pinnacle of Russian fighter development since the Su-27 entered service in 1985. It was developed as the heavy fighter component of the Soviet Union's 'high–low' mix, alongside the smaller, cheaper and shorter-ranged Mig-29. Together, the two types were roughly analogous to the US's high–low F-15 and F-16 fighter mix developed during the same period.

The Su-27 was initially developed as an air superiority fighter with only a limited ability to employ unguided air-to-ground munitions in a strike role. However, since the Cold War, Russia has developed a line of multirole fighters from the basic airframe. All of Russia's frontline Flankers have been modernised with multifunction digital cockpit displays, significantly reducing pilot workload and allowing more mental capacity for tactical decision-making and weapons employment. This is important given one of the persistent criticisms of the original Su-27 (and Mig-29) series was its very high pilot workload, which limited practical situational awareness and combat effectiveness.[36] The core Flanker airframe design generates a huge amount of aerodynamic lift and remains controllable at high angles of attack (alpha) because the main fuselage body generates lift and the wings' leading edges are extended to blend into the nose section.[37]

32. *Ibid.*
33. See, for example, *RT*, 'Russia's Su-57 Jet Gets Hypersonic Missile That Can Shoot Down Enemy Aircraft "300km Away"', 26 September 2018, <https://www.rt.com/news/439553-russia-long-range-missile/>, accessed 9 July 2019.
34. Author correspondence with Douglas Barrie, IISS, August 2020.
35. Author correspondence with Douglas Barrie, IISS, 9 July 2020.
36. Author conversation with Ukrainian Air Force Su-27 pilot, RAF Fairford, 21 July 2019.
37. *Ibid.*

The most modern and capable Russian variant is the Su-35S 'Flanker-E', which is an air-superiority-focused design with some multirole capabilities and represents the most straightforward evolution of the Su-27. It remains Russia's most advanced frontline fighter in active service, with 88 delivered to frontline squadrons and an order for 30 more signed in 2020.[38] In comparison to the Su-27, the Su-35S has a greatly improved thrust-to-weight ratio, thrust-vectoring capabilities and supercruise performance from its AL-41F engines, a much more powerful radar, avionics, ESM and ECM suite, and it can carry more missiles.[39]

Figure 1: VKS Sukhoi Su-35S 'Flanker-E' on Take-Off in 2016

Source: Dmitry Terekhov/Wikimedia Commons/CC BY-SA 2.0.

As such, the Su-35S arguably represents the pinnacle of the core design philosophy behind the Flanker family – maximising thrust, subsonic agility and brute power in terms of radar performance. The AL-41F-1S engines produce significantly more thrust than the AL-31F series

38. A total of 92 Su-35Ss have been delivered to the VKS as of August 2020, but four were assigned to the 'Russian Knights' aerobatic display team, leaving 88 in combat units. See *TASS*, 'Aerobatic Team Russian Knights to Get Four Highly Maneuverable Su-35S Planes in November', 5 November 2019, <https://tass.com/defense/1086958>, accessed 17 September 2020.
39. United Aircraft Corporation, 'Su-35', <https://www.uacrussia.ru/en/aircraft/lineup/military/su-35/#design-features>, accessed 19 June 2020.

which power the earlier Su-27/30 variants, giving the Su-35S significantly better high-altitude performance, including supercruise capability with light weapon loads, and boosting the effective range of its missiles in combat.[40] The addition of multi-axis thrust vectoring (where the engine exhaust nozzles can be moved independently to change the direction of thrust from each engine in flight) gives an improvement on the Flanker family's already impressive agility, especially at very low airspeeds. Thrust vectoring grants so-called 'supermanoeuvrability', whereby the pilot can continue to point the aircraft's nose in a desired direction and maintain full control authority after the aircraft has departed from aerodynamic flight (where the wings have stalled and air flow over the control surfaces is insufficient).

This supermanoeuvrability allows seemingly gravity-defying performances in air shows and makes the Su-35S an even more formidable slow-speed WVR opponent than previous Flanker versions in a one-on-one situation.[41] However, these post-stall manoeuvres involve excessive bleeding of energy, and as such, using them in combat would involve trading a nearly guaranteed missile shot at one opponent for leaving oneself an easy kill for any other aircraft in the area. Since fighters operate as pairs or four-ships as basic tactical formations, this is a significant consideration.[42] Supermanoeuvrability is also unlikely to significantly improve the ability to defeat modern dogfighting missiles, which are capable of much more aggressive changes of direction (up to 50G) than any human pilot could sustain. Indeed, the afterburner usage for increased thrust during such manoeuvres would actually increase the Flanker's already large visual and heat signature, potentially making it harder to successfully evade IR-guided missiles. As such, supermanoeuvrability is unlikely to give major practical advantages in realistic combat scenarios.

The N035 Irbis-E radar fitted to the Su-35S is an X-band hybrid passive electronically scanned array (PESA) radar, with some AESA features and a power rating of 20 Kw (which is high for a fighter). This is around five times more powerful than the original N001 Bars radar of the Su-27 and is still coupled with a large array size (aperture) made possible by the capacious nose of the Flanker series. The manufacturer claims that this results in an effective detection range of between 350 and 400 km against a target with a 3 m^2 RCS – which is roughly comparable to a fourth-generation fighter without LO design features.[43] It is capable of up to eight simultaneous TWS engagements using active radar seeker missiles, as well as offering air-to-ground scanning capabilities. Coupled with a modern digital cockpit, the Irbis-E offers Su-35S pilots excellent frontal-aspect situational awareness against traditional non-VLO threats when actively scanning. However, the lack of any LPI/LPD capabilities and the unique radar signature (since the Irbis-E

40. For AL-41F details, see Rosoboronexport, 'AL-41F-1S Turbofan Aircraft Engine', <http://roe.ru/eng/catalog/aerospace-systems/engines/al-41f-1s/>, accessed 19 June 2020.
41. For more details on Su-35 supermanoeuvre displays, see Hugh Harkins, *Sukhoi Su-35S 'Flanker' E: Russia's 4th ++ Generation Super-Manoeuvrability Fighter* (London: Centurion Publishing, 2015), p. 127.
42. Emphasis on this was repeated in multiple author interviews with RAF, USAF, Armée de l'Air, Luftwaffe and Aeronautica Militare fighter pilots since 2014.
43. V V Tikhomirov Research Institute of Instrumentation, 'Irbis-E', <https://www.niip.ru/catalog/eksportnaya-produktsiya/rlsu-irbis-e/>, accessed 22 June 2020.

is not currently used by any other aircraft) mean that when actively scanning, the emissions will reveal and identify the Su-35S to hostile passive ESM suites from extremely long ranges. Furthermore, while the frontal RCS of VLO threats like the F-35 and F-22 is classified, effective detection ranges would be an order of magnitude shorter, and with their LPI/LPD AESA radars, the two US stealth fighters would certainly detect an Su-35S from much further away than the Su-35S could detect them even under ideal circumstances. Against the American F-15C, European Eurofighter Typhoon and French Dassault Rafale, the Su-35S would likely be able to match fighter-vs-fighter situational awareness in the active regime, with sufficiently powerful radars on all sides to make detection at distances well in excess of a missile's effective range likely. In practice, however, the reliance on active radar scanning and the huge radar cross section of the Su-35S itself mean that it would almost certainly be located and identified by a combination of passive and, if necessary, active sensors by these Western air superiority types at very long ranges. This is a significant drawback given that Western BVR missiles, such as the AIM-120C/D and Meteor, outrange the R-77-1 and R-27ER/ET available to Russian Flankers under comparable launch conditions.[44]

Like all Flanker types, the Su-35S features a passive infrared scan and track (IRST) sensor on the nose – in this case, the OLS-35. Sukhoi claims that the OLS-35 can detect and track head-on fighter-size threats from up to 50 km and up to 90 km in a tail-chase.[45] The combination of IRST and the R-27ET IR-seeking BVR missile gives the Su-35S a potentially potent, fully passive combat capability within approximately 50 km, albeit one that is heavily dependent on atmospheric conditions and sufficient offboard information to know where to focus the IRST's comparatively narrow search field of regard. In an actual combat situation, both sides would also draw on offboard situational awareness data from ground- and air-based wide area surveillance assets like AWACS. However, NATO datalinks and intelligence, surveillance and reconnaissance (ISR) assets are significantly more advanced and integrated than those which the VKS can field.[46] Furthermore, Western passive sensors, like the F-35's IRST/EODAS and the Typhoon's PIRATE IRST, are able to take advantage of improved practical limits on sensitivity thanks to superior onboard electronic post-processing to filter out false positives.[47] Since all Flankers are significantly physically larger than their international competitors (with the exception of the F-22 and Chinese J-20) and rely on extremely high-thrust engines with a partially exposed aft installation, they will also be easier to detect in the IR and visual spectra. Therefore, in the passive domain, the Su-35S and all other Russian Flanker variants are likely to be significantly out-detected by Western competitors, rendering them disadvantaged in terms of pilot situational awareness.

44. For example, see Reuben F Johnson, 'PLAAF Senior Pilot Reveals Poor Performance in Joint Exercise With RTAF', *AIN Online*, 8 February 2020, <https://www.ainonline.com/aviation-news/defense/2020-02-08/plaaf-senior-pilot-reveals-poor-performance-joint-exercise-rtaf>, accessed 15 July 2020.
45. Dave Majumdar, 'Stealth No More?: Russia's Su-35 Fighter Might Be Able to Track an F-22 Raptor', *National Interest*, 19 April 2019.
46. For more information, see Justin Bronk, 'The Future of Air C2 and AEW: E-3 Sentry, Threat Technologies and Future Replacement Options', *RUSI Occasional Papers* (June 2017).
47. Author interview with RAF staff officer in the Typhoon programme, High Wycombe, 20 February 2015.

The Su-35S and Su-27SM are heavily optimised for the air superiority role. While they can carry and drop most weapons in the Russian aerial arsenal, it is unclear what degree of practical accuracy can be obtained with precision-guided munitions (PGMs) which are not cued in by radar designation, since the Russian air force lacks targeting pods which are a mainstay of Western multirole fighter loadouts.[48] In the absence of a targeting pod capable of laser designation, laser-guided bombs can only be dropped accurately on targets which have been designated via 'buddy-lasing' by another aircraft or ground forces. Furthermore, missiles with IR or TV seekers would have to be slewed onto target manually from the cockpit, using the weapon seeker head itself for target acquisition, recognition and designation. Seeker heads are significantly lower-resolution sensors, with a narrower field of regard and much reduced range, compared to modern targeting pod optics. They are also unable to rotate freely like the sensor ball on a targeting pod, being limited to a frontal view ahead of the missile on its underwing rail. As a result, a fighter, such as the Su-35S, which is described as multirole but is not equipped with targeting pods or an internal system to perform the same function, has very limited precision attack capabilities against dynamic targets, such as moving vehicles on the battlefield. The pilot has a limited sensor view with IR- or TV-guided munitions, relying on the forward-looking weapon seekers themselves, and broadly having to 'aim' the aircraft towards the target location while searching for, acquiring, identifying and then launching a weapon against it. They also cannot self-designate targets for strikes with laser-guided weapons. Radar-guided, anti-radiation seeking and GPS/GLONASS guided munitions can, however, be employed effectively by Su-35S and the few remaining modernised legacy Su-27SM fighters.

The immature state of Russian PGMs compared to their Western equivalents, and lack of targeting pods, means that effective employment in complex combat situations generates a much higher pilot workload. As a result, much like previous generations of Western fighter-bombers like the F-15E and Tornado IDS, the Flanker variants designed with a focus on multirole or strike operations have a crew of two. These include the multirole Su-30M2 and Su-30SM, which are relatively straightforward evolutions of the twin-seat Su-27UB trainer airframe with combat systems in the rear cockpit to control sensors and weapons employment. Given the Russian preference for somewhat outmoded TV-guided weapons over more expensive and complex IR/EO, GPS/GLONASS or millimetric radar seeker guidance, the second crew member is extremely valuable. During a TV-guided attack, the weapon broadcasts back video imagery from its seeker during its terminal dive into the target area, and the crew of the launch aircraft must use this footage to identify and remotely guide the weapon to the target itself. With limited time and sensor resolution, this is a demanding task in many circumstances, and is made much easier if the crew member conducting the remote TV-guided attack is not also having to fly the aircraft at the same time.

48. Butowski, *Russia's Air-Launched Weapons*, pp. 40–41. See also Dave Majumdar, 'The Russian Air Force Was Always Behind the West in One Key Area (Until Now)', *National Interest*, 11 May 2016.

Figure 2: VKS Sukhoi Su-30SM in Flight in 2014

Source: Alex Beltyukov/Wikimedia Commons/CC BY-SA 3.0.

Both the Su-30M2 and the Su-30SM have superior practical strike capabilities compared to the Su-35S as a result of the greater crew capacity to fly and position the aircraft, manage overall situational awareness and also acquire, identify and attack targets with PGMs. They also have slightly reduced performance compared to the Su-35S due to the weight, drag and fuel capacity penalties of the larger cockpit section. The Su-30M2 is the less advanced of the two, with an obsolescent N001V radar and without thrust vectoring or forward canards to improve agility. The Su-30SM has canards and thrust vectoring, with a more advanced N011M Bars-R PESA radar which is only marginally less capable than the Irbis-E on the Su-35. Aside from greater practical multirole capabilities and generally increased crew capacity to cope with complex combat situations, the Su-30M2 and Su-30SM share the broad strengths and drawbacks of the Su-35S. They represent a similar but marginally less capable threat to Western aircraft, and a greater threat to ground forces.

The ‘Fullback’

An altogether more specialised Flanker derivative, however, is the Su-34 bomber which has been given a new and separate NATO codename: ‘Fullback’. This is a dedicated strike aircraft developed to supplement and eventually replace the ageing Su-24M Fencer. Compared to the

Su-27/30/35 family, it features a distinctive new armoured side-by-side crew compartment, Sh-141 PESA multimode radar system optimised for ground attack, and an improved rearward-facing defensive warning radar in an enlarged tail 'sting'.[49] It also features an internal, retractable EO/IR targeting system with laser designation capabilities called 'Platan', which is mounted between the engine intakes underneath the fuselage and can be thought of as an aerodynamically cleaner alternative to a targeting pod, but with significantly worse field of view and resolution.[50] The fact that the modernised Su-34M will include a new external targeting pod suggests that the Platan system has proven less than optimal in service.[51]

The aircraft also features the SVP-24 GPS/GLONASS blind bombing system, which allows the dropping of unguided bombs with significantly improved accuracy in level flight from medium altitudes, although results are still much less precise than those achievable with dedicated PGMs. In effect, this system gives Russian aircraft an analogue to the common Western GPS- or aircraft sensor point of interest (SPI)-cued continuously computed release point (CCRP) delivery mode.[52] SVP-24 system accuracy under representative (semi-permissive) combat conditions, such as those encountered during Russian deployments to aid President Bashar al-Assad's regime in Syria, is estimated to be around 20–25 m circular error probable (CEP).[53] This is sufficient to give a reasonable likelihood of damage to fixed targets with salvo releases of unguided bombs, even in poor weather conditions or at night, but is significantly less precise than the latest Western standards for GPS or laser-guided PGMs.

49. Yefim Gordon and Dmitriy Komissarov, *Russian Tactical Aviation Since 2001* (Manchester: Hikoki Publications, 2017), pp. 89–90.
50. Butowski, *Russia's Air-Launched Weapons*, pp. 40–41.
51. *Ibid.*
52. CCRP refers to a weapons delivery mode where the pilot designates a target and then flies an indicated course calculated by the aircraft's systems. When the correct release point is reached, the weapon will be automatically released and should land near the target (with finetuning guidance usually provided once released by laser designation or a GPS system on the weapon itself). The alternative is known as continuously computed impact point (CCIP) mode, where the aircraft's systems constantly calculate roughly where a weapon would impact if fired/dropped at that moment in flight, allowing pilots to 'fly' the CCIP marker over a visually identified target (usually in a dive) and manually release the weapon.
53. Gordon and Komissarov, *Russian Tactical Aviation Since 2001*, p. 236.

Figure 3: VKS Sukhoi Su-34 on Take-Off in 2012

Source: Alex Beltyukov/Wikimedia Commons/CC BY-SA 3.0.

The Su-34 is the closest Russian analogue to the F-15E Strike Eagle in US Air Force service, with a long range and respectable but somewhat degraded air-to-air capabilities compared to other Flankers. It is also able to carry a heavy load of varied and sometimes very large external stores for close air support, interdiction, deep strike and suppression of enemy air defences (SEAD) missions. It has seen extensive use by the Russian Air Force in Syria, as one of the only high-performance platforms with the capability to effectively employ a broad range of PGMs. The Su-34 currently forms the core of VKS tactical strike firepower. They (and the Su-35S) are also typically deployed with upgraded L175V Khibiny ECM wingtip pods, a more advanced development of the L005S Sorbtsiya pods which are an option for all modernised Flanker variants.[54] Both sets of pods are intended to degrade hostile ground-based and aerial radar effectiveness by jamming, but the Khibiny pods have a greater operating frequency range and greater power.

54. *Ibid.*, p. 90.

Other Strike Aircraft

Alongside the Su-34 Fullback fleet, the remaining Sukhoi Su-24M Fencer and Su-25SM Frogfoot aircraft still provide significant striking power against a wide range of ground targets, but with almost no capabilities against other aircraft. The swing-wing supersonic Su-24M has a primary anti-shipping strike mission with both the VKS and MA VMF, alongside the much larger Tupolev Tu-22M3 Backfire bombers, employing a range of (often very large) subsonic and supersonic anti-ship missiles.[55] However, as they have demonstrated in Syria, the Su-24M fleet is also capable of dropping large quantities of conventional unguided and laser/TV-guided bombs.[56] Like the Platan system on the Su-34 that will replace it, the Su-24M does have an internal TV-based target acquisition and laser-designating system with a limited field of regard, called 'Kayra'. This enables it to self-designate for attacks in daylight conditions with laser-guided bombs and missiles.[57] The Su-24M also uses the SVP-24 GPS/GLONASS blind bombing system to make use of Russia's huge stocks of cheap unguided munitions. The side-by-side layout for the two crew helps improve crew capacity and coordination during complex combat situations and improves the employment capabilities of PGMs.

The Su-25SM is the direct Russian equivalent to the US A-10C Thunderbolt II 'Warthog', being designed specifically for close air support and battlefield interdiction in support of friendly forces at low level. As such, it is a subsonic, armoured attack aircraft with a powerful internal cannon and ability to carry large quantities of widely varied ordnance – both precision-guided and unguided. The Su-25SM has a nose-mounted, forward-looking infrared and EO imaging system which can also laser designate targets for laser-guided rockets. However, as with the Su-34 and Su-24M internal systems, this has a relatively limited field of regard and resolution compared to Western targeting pods. The single pilot also has to struggle with a relatively cluttered cockpit and the complexity of Russian PGMs while attempting to strike targets at low altitudes – meaning pilot workload is high.

Both the Su-24M and Su-25SM fleet would pose a significant threat to ground forces which did not have modern air defences and/or defensive fighter cover, but are vulnerable to modern fighters due to their large radar signatures and very limited air-to-air situational awareness generation options. The Su-24Ms are slowly being retired from active service as deliveries of the newer Su-34 continue.[58]

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55. Butowski, *Russia's Air-Launched Weapons*, pp. 10–13.
56. James Kearney, 'Russia's Airstrike Rules of Engagement Reviewed', Action On Armed Violence, 14 May 2019, <https://aoav.org.uk/2019/an-assessment-of-russias-roe/>, accessed 30 July 2020.
57. Butowski, *Russia's Air-Launched Weapons*, p. 40.
58. Hugh Harkins, *Su-34: Russia's 4th+ Generation Strike Fighter* (London: Centurion Publishing, 2019), pp. 20–43.

Russian Bombers

Although not fast jets, it is important to acknowledge that alongside the tactical strike aircraft, Russia also operates a sizeable strategic bomber fleet composed of Tupolev Tu-95MS 'Bear-H', Tu-22M3 'Backfire' and Tu-160M 'Blackjack' aircraft. While the Backfire and Blackjack are both large supersonic swing-wing aircraft, the Bear-H is a turboprop-powered subsonic aircraft based on an airframe from the 1950s. The Bear-H and Blackjack are primarily dedicated to the nuclear deterrence mission carrying large numbers of nuclear-tipped cruise missiles. The Tu-22M3s, by contrast, are primarily configured to attack American carrier battlegroups with a range of very large, supersonic, nuclear- or conventional-tipped anti-ship missiles. The Tu-22M3s also performed conventional heavy-bombardment missions with unguided bombs and the SVP-24 blind bombing system in Syria on several occasions in 2015 and 2017.[59] However, in a conflict with NATO, the strategic bomber force would almost certainly be confined to nuclear deterrence/attack duties and patrols to counter movements of naval task groups, rather than attacking ground forces. That Russia still sees a major role for these bombers is demonstrated by the fact that production of new-build Tu-160M bombers has started, and the Tu-22M3M upgrade programme is ongoing, having delivered the second overhauled airframe in 2019.[60]

Swansong of the Fulcrum

For the final decade of the Cold War and much of the subsequent decades, the Mikoyan-Gurevich Mig-29 'Fulcrum' stood alongside the larger Flanker as the pacing threat for Western air forces. With the reunification of Germany at the end of the Cold War, a core NATO state inherited East Germany's new Mig-29 fleet and extensively evaluated it in exercises for the next decade. They found that the aircraft's exceptional thrust-to-weight ratio, agility and the first operational helmet-cued sighting system for the R-73 IR-guided dogfighting missile made it almost unbeatable in a 1v1 WVR engagement.[61] For its time, the radar was also competitive with those carried by other light fighters such as the American F-16C.

The modern Mig-29SMT version was initially produced for export to Algeria with: a modernised N010M Zhuk-M radar; a 25% increase in fuel compared to the older Mig-29S; an in-flight refuelling probe; and the capability to deliver modern PGMs. However, when Algeria cancelled the contract following initial deliveries in 2007 due to quality control concerns, the Russian Ministry of Defence eventually purchased the 34 suddenly unwanted Mig-29SMTs for the VKS. These were later joined by 16 additional newly manufactured aircraft.[62] The primary VKS

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59. *TASS*, 'Russian Tu-22M3 Bombers Hit Terrorists Targets in Syria's Deir ez-Zor Province', 26 November 2017, <https://tass.com/defense/977512>, accessed 6 July 2020.
60. Vladimir Karnozov, 'Tupolev Flies Modernized "Blackjack"', *AIN Online*, 6 February 2020, <https://www.ainonline.com/aviation-news/defense/2020-02-06/tupolev-flies-modernized-blackjack>, accessed 6 July 2020; Mark B Schneider, 'The Renewed Backfire Bomber Threat to the U.S. Navy', US Naval Institute, *Proceedings* (Vol. 145/1/1, 391, January 2019).
61. Author interview with former Luftwaffe Mig-29 and Eurofighter pilot, Berlin, 14 December 2018.
62. Gordon and Komissarov, *Russian Tactical Aviation Since 2001*, pp. 115–24.

operator of the type is the elite 116th Combat Application Training Centre of Fighter Aviation (116 UTsBPr IA) which serves as the VKS's aggressor training unit – tasked with emulating hostile combat aircraft and tactics in exercises against regular units.[63] These pilots get significantly more flying hours than any other VKS fighter units, at around 120 hours per year.[64]

Figure 4: VKS Mikoyan Mig-29SMT on Take-Off in 2013

Source: Alex Beltyukov/Wikimedia Commons/CC BY-SA 3.0.

The major weaknesses of previous Mig-29 variants was inadequate range due to low fuel capacity and engines with high fuel consumption.[65] The Mig-29SMT (T standing for *tuplivo* [fuel]) addresses this by adding additional capacity in a humped dorsal fuselage section and a large removable under-fuselage tank. However, the net effect of the additional fuel and the weight growth from upgraded avionics and other equipment has been to destroy the one major advantage that the aircraft had during the Cold War: its exceptional thrust-to-weight ratio and agility in WVR engagements. As a result, the Mig-29SMT represents a slightly less expensive but significantly less capable alternative to the Su-27SM/30/35 family.

63. Butowski, *Flashpoint Russia*, pp. 32–33.
64. *Ibid.*, p. 33.
65. Author interview with former Luftwaffe Mig-29 and Eurofighter pilot, Berlin, 14 December 2018.

The Russian Naval Aviation arm, the MA VMF, flies the single-seat Mig-29K and twin-seat Mig-29KUB airframes which have been navalised for use on the *Admiral Kuznetsov*, Russia's sole aircraft carrier. The ship is in deep refit and repair until at least 2022 following the accidental sinking of its dry dock and subsequent fire on board.[66] These aircraft are intended to progressively replace the non-PGM-capable Su-33 navalised Flanker. However, in recent deployments, the *Admiral Kuznetsov* operated a mix of both types, including during the ill-fated Syrian deployment where a Mig-29K and a Su-33 were lost in the Mediterranean due to deck landing accidents.[67]

The latest derivative of the Fulcrum family is the Mig-35, which was developed from the naval single-seat Mig-29K and twin-seat Mig-29KUB airframes, with more underwing hardpoints and a claimed AESA radar, the Zhuk-AM.[68] However, the small initial batch for the VKS has been delivered without the AESA radar due to delays in producing an operational production set.[69] It remains unclear when Russia will be able to field a mature AESA radar on a fighter platform.

The additional logistical expenses involved in operating small fleets of different types further reduce the attractiveness of significant orders of Mig-29 and the follow-on Mig-35 derivative for the VKS, which is perfectly satisfied with the Su-30SM and Su-35S (which are already in large-scale production). As a result, only 50 Mig-29SMTs and six Mig-35s have been ordered so far for the VKS, mostly as an industrial support policy to keep Mikoyan in business and improve export prospects for the type.[70]

The 'Foxhound'

The Mig-31 'Foxhound' represents a uniquely Russian category of combat aircraft in the modern world, being an extremely large and fast interceptor designed to patrol vast swathes of airspace at high altitudes. The Foxhound is designed around two huge engines, a large and very powerful Zaslon-M PESA radar and long-range R-33 or R-37M missiles.[71] The purpose of this combination is to provide airborne defence in depth for Russia against airborne threats – first and foremost

66. Xavier Vavasseur, 'Russia's Aircraft Carrier Admiral Kuznetsov to Be Ready for Trials by Fall 2022', *Naval News*, 12 May 2020, <https://www.navalnews.com/naval-news/2020/05/russias-aircraft-carrier-admiral-kuznetsov-to-be-ready-for-trials-by-fall-2022/>, accessed 3 June 2020.
67. Sam LaGrone, 'Second Russian Carrier-Based Fighter Crashes, Pilot Safe', *USNI News*, 5 December 2016, <https://news.usni.org/2016/12/05/second-russian-carrier-based-fighter-crashes-pilot-safe>, accessed 6 July 2020.
68. Gordon and Komissarov, *Russian Tactical Aviation Since 2001*, p. 287.
69. Georg Mader, 'What Does the MiG-35 Bring to Air Combat? Interview with Anastasia Kravchenko', *Defence iQ*, 3 July 2019, <https://www.defenceiq.com/air-forces-military-aircraft/articles/what-does-the-mig-35-bring-to-air-combat-interview-with-anastasia-kravchenko>, accessed 6 July 2020.
70. Gordon and Komissarov, *Russian Tactical Aviation Since 2001*, pp. 286–88. See also *RIA*, 'VKS poluchili pervye dva novejshih istrebitelja MiG-35' ['VKS Received the First Two Latest MiG-35 Fighter'], 17 June 2019, <https://ria.ru/20190617/1555619124.html>, accessed 3 July 2020.
71. Gordon and Komissarov, *Russian Tactical Aviation Since 2001*, pp. 124–34.

low-flying cruise missile salvos. As such, the Mig-31 is not designed with any LO features and is not concerned with LPI/LPD radar capabilities to hide its presence. Instead, it is the big stick of the combat aviation world, designed to be able to detect and track cruise missiles and other difficult targets through brute force radar techniques even in the face of significant hostile EW, and fire missiles at those targets from outside the effective range of hostile fighters' missiles. The latest Mig-31BM variant has apparently been upgraded with significantly improved datalinks to allow it to play an airspace quarterback role in conjunction with Russia's ground-based IADS.[72] A flight of Mig-31BMs can operate at very high altitudes behind Russia's forward IADS elements, to provide the SAMs with long-range target cueing via datalink onto low-flying targets which are difficult for the ground-based sensors to detect due to terrain and curvature-of-the-earth obstruction. While there is reason to believe that the Mig-31BM's datalinks and mission systems still have reliability issues, it has been equipped with datalinks since the late 1970s.

As a core part of Russia's air defence network, it has also received priority for modern electronics upgrades.[73] With a 200-km-class missile, they can also pose a significant threat to tactical aviation and enabler aircraft at ranges that exceed those of the standard NATO AIM-120C/D AMRAAM family.[74] The fact that their Zaslon-M radar is specifically optimised for detecting and engaging terrain-hugging cruise missile salvos also makes the Mig-31 family a potentially serious threat to other Western capabilities which rely on very low-altitude flight to mask them from threats – such as attack and reconnaissance helicopters. Even if a flight of Mig-31s do not themselves attack such targets, they can relay position and heading information via datalink to other 'shooters' on the ground.

72. *Ibid.*
73. For information on potential limitations, see Joseph Trevithick, 'Russian MiG-31 Foxhound Shot Down Its Wingman During Disastrous Live Fire Exercise', *The Warzone*, 23 April 2019.
74. Butowski, *Russia's Air-Launched Weapons*, pp. 55–56.

Figure 5: MiG-31BM Armed With R-33 Missiles

Source: Fedor Leukhin/Wikimedia Commons/CC BY-SA 2.0.

The large size and excellent high-altitude performance of the Mig-31 airframe have also led to its adaptation into a specialised missile launch platform. The fleet of 10 Mig-31BPs (also known as Mig-31K) can carry and launch the hypersonic Kh-47M2 Kinzhal (also known by its NATO codename, AS-24 Killjoy) missile.[75] Since it can bypass all known missile defence systems, the Kinzhal is intended to hold heavily defended targets – such as aircraft carriers, command centres and logistics hubs – at risk well beyond 1,000 km from the launch area.[76] Mig-31BPs have also been spotted with what appear to be anti-satellite missiles.[77]

However, for all the brute power of the Foxhound, it remains vulnerable to modern fighters if they are able to close to within effective missile range, as it has a huge radar cross-section, heat and visual signature and lacks high levels of agility for terminal-stage missile evasion manoeuvres. The questionable performance of its Zaslon-M radar against VLO platforms, such as the F-22 and F-35, might allow those platforms to get within effective range with AMRAAM, while the integration of the ramjet-powered very-long-range Meteor missile on the Eurofighter Typhoon, Dassault Rafale and Saab Gripen gives those platforms a weapon with comparable,

75. Butowski, *Flashpoint Russia*, p. 141.
76. Tyler Rogoway and Ivan Voukadinov, 'Exclusive: Russian MiG-31 Foxhound Carrying Huge Mystery Missile Emerges Near Moscow', *The Warzone*, 29 September 2018.
77. *Ibid.*

and possibly superior, NEZ range to the R-37M.[78] As such, the Mig-31BMs would likely have to remain well within the defensive coverage of Russia's IADS in any direct clash with NATO in order to prevent attrition from VLO offensive counter-air (OCA) sweeps by F-22s and potentially F-35s, as well as remaining out of range of Meteor shots from European fast jets on defensive combat air patrols. This will limit the effectiveness of their missiles to targets attempting to breach the IADS but would not prevent them contributing valuable overhead surveillance and potentially target grade track data to the ground-based systems.

Russia's Next Generation

The introduction of the F-22 Raptor by the US in 2005 gave NATO a fighter capable of completely overmatching all existing Russian combat aircraft due to its combination of VLO (stealth) signature, powerful LPI/LPD-capable AESA radar and unmatched aerodynamic performance at high altitudes. Russia was well aware of the F-22 development programme and the Su-57 is the result of their efforts to develop a broadly comparable fighter aircraft. The Su-57 is a heavily modified derivative of the Flanker airframe, shaped to minimise frontal aspect X-band RCS while retaining supermanoeuvrability. As such, it can be thought of as a design hybrid which incorporates features of the American F-22 and the Su-27/35 Flanker family. Notable sources of radar reflections include the unusual fully moving leading-edge root extension (LERX) control surfaces and actuators, cockpit canopy design, ram air intakes at the base of the canted vertical stabilisers, IRST sensor in front of the canopy and the only partially shrouded jet engine turbine faces. The latter is due to the 'flattened Flanker' blended wing-body shape, coupled with two large central weapons bays between the intake trunks, leaving insufficient space for a full 's-curve' to hide the turbine faces as used on the F-22. These features are likely a result of comparative Russian inexperience in designing and building stealth aircraft, coupled with budgetary limitations. They, along with limited manufacturing tolerances and quality control issues, mean that the effective RCS of the Su-57 will be at least an order of magnitude larger than the F-35 and several orders of magnitude larger than the F-22.[79] On the other hand, the Su-57 will still be much harder to detect than existing Russian combat aircraft thanks to its RCS-reducing trapezoidal wing and smaller canted all-moving vertical stabilisers compared to the Flanker family, as well as having provision for internal weapons carriage and an angled main radar array to further reduce returns.[80]

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78. The R-37M has a maximum ballistic range (Rmax) in the order of 200 km when fired from high speeds and altitudes. For details on the R-37M, see Butowski, *Russia's Air-Launched Weapons*, pp. 55–56. This is similar to the higher-end, open-source claims of Rmax for Meteor. However, as a ramjet-powered design, the Meteor will retain much more energy at longer ranges, thus increasing the size of the no-escape zone, potentially beyond that of the R-37M, especially if both launch fighters are high and fast. For more information on this, see Rogoway, 'Is the European Meteor Air-To-Air Missile Really the Best in the World?'.
79. Author calculations based on interviews with military and civilian radar cross-section and airframe design specialists, May and July 2020.
80. Gordon and Komissarov, *Russian Tactical Aviation Since 2001*, pp. 270–71.

Figure 6: Sukhoi Su-57 at MAKS Airshow 2019

Source: Anna Zvereva/Wikimedia Commons/CC BY-SA 2.0.

The sensor suite intended to equip the production-standard Su-57 is also a significant departure from previous Russian fighters. Its main N036 Belka radar is an X-band AESA array and is supplemented with two additional smaller side-facing X-band arrays on each side of the nose to provide a wider field of regard and allow 'beaming'.[81] Beaming is a tactic where a fighter maintains a STT or TWS lock on a target during a missile engagement while flying at close to 90 degrees to the target's course to make it harder for hostile fire control and missile radars to maintain a lock on it due to reduced doppler shift.[82] The Su-57 is also intended to feature an innovative

81. *Ibid.*, p. 271.
82. Radars are programmed to filter out energy reflected from things other than potential threats by sorting them according to relative speed using doppler shift. Anything moving too slowly to be a potential target will generally be ignored by older radars due to the doppler shift on their reflected energy showing that they are not within the defined search parameters. By flying at roughly 90 degrees to the incoming threat, a fighter tries to make its relative speed as close to zero as possible, to encourage the enemy radar to filter it out and hence lose lock. However, modern radars are increasingly capable of compensating for such notching or beaming tactics. For more information, see Tyler Rogoway, 'No, The Su-57 Isn't "Junk:" Six Features We Like on Russia's New Fighter', *The Warzone*, 30 April 2018.

N036L-1-01 L-band (lower frequency) array in the leading edge of each wing to enhance situational awareness against hostile VLO aircraft designed to evade X- and Ku-band radars.[83] In terms of sensors, therefore, the Su-57 has the potential to offer its pilots significantly greater situational awareness-gathering capabilities, especially against LO or VLO aircraft. However, there are two important unanswered questions. The first is whether Russian engineers have managed to successfully get the various innovative radar arrays on the Su-57 working as intended and feeding into a single situational awareness picture without mutual interference or duplicated contacts. The second is whether or not the Su-57's radars offer reliable LPI/LPD capabilities.

Given the difficulties Russian industry has faced in bringing previous single-array AESA radar capabilities to fighters, such as the Mig-35's Zhuk-AM and the general lack of compact AESAs within the Russian Armed Forces as a whole, the Su-57's complex multi-array AESA radar is almost certainly a work in progress. The same can be said for the L-band 'counter-stealth' wing-mounted arrays, although the Soviet Union consistently developed metre and decimetre wavelength radars during the Cold War for ground-based applications, meaning Russian industry has a much more established pedigree in this field than most.[84] However, the expensive saga of the F-35's sensor-fusion capabilities has been well documented and is evidence of how difficult automatic cross-cueing, cross-referencing and fusing data from multiple different sensor types within a fighter aircraft is, even for a company with Lockheed Martin's budget and extensive experience designing and manufacturing a fifth-generation fighter.[85] Russian industry has suffered from a lack of high-end micro-electronic components since the imposition of Western sanctions in response to the annexation of Crimea, increasing the difficulties inherent in developing such a complex fused multiple-array sensor suite to a level of maturity where it can be considered ready for frontline service.[86] Since Russia also lacks practical experience with AESA radars, advanced LPI/LPD capabilities sufficient to hide the Su-57 from modern Western ESM suites when actively scanning are also likely to be a future aspiration rather than a current capability.

In summary, the Su-57 is not a direct competitor to the US F-22 (or Chinese J-20) as a VLO air superiority machine. It is, however, a LO design which cures most of the weaknesses of the Flanker family in modern air combat situations – specifically the large signature of the Flanker which makes it easy to detect at very long ranges, and the lack of an AESA radar which leaves even the Su-35S with little alternative than to rely on brute power active scanning for situational awareness. Even though the latest Western airborne radar sets, especially AESA types such as the F-35's APG-81 and the F-15C's large APG-63(V)3, are likely to detect the Su-57 from

83. Gordon and Komissarov, *Russian Tactical Aviation Since 2001*, p. 271.
84. See Carlo Kopp, 'Russian / PLA Low Band Surveillance Radars (Counter Low Observable Technology Radars)', *Air Power Australia*, last updated April 2012, <http://www.ausairpower.net/APA-Rus-Low-Band-Radars.html>, accessed 6 July 2020.
85. See, for example, Director, Operational Test & Evaluation, 'F-35 Joint Strike Fighter', FY16 DoD Program, 2017, pp. 67, 70, <https://www.dote.osd.mil/Portals/97/pub/reports/FY2016/dod/2016f35jsf.pdf?ver=2019-08-22-105333-997>, accessed 6 July 2020.
86. For more information, see Igor Sutyagin and Justin Bronk, *Russia's New Ground Forces: Capabilities, Limitations and Implications for International Security* (London: Taylor and Francis, 2017), pp. 86–88.

fairly long ranges compared to a true VLO machine, it should allow the VKS to compete in situational awareness terms with the latest non-fifth-generation aircraft. In a predominantly passive sensor engagement, where detection ranges might be relatively close for both sides, the extreme manoeuvrability of the Su-57 coupled with internal carriage capacity for upgraded active radar-guided K-77M and K-74M2 dogfighting missiles should allow it to pose a significant threat to all but the F-22 and F-35.[87] Over time, if Russia can bring the sensor suite, engines and weapons suite to maturity, including LPI/LPD and counter-stealth L-band radar capabilities, the type will sit in an unusual niche somewhere between the modernised fourth-generation and true fifth-generation fighters.

However, there are significant doubts about the scale of Su-57 production and the funding required to mature the aircraft's sensors, avionics and dedicated weapons systems. After announcing in 2018 that series production of the aircraft would be deferred indefinitely, the Russian government changed track in 2019 and declared an intention to order 76 Su-57s by 2028.[88] A $2.63 billion cost was announced by President Vladimir Putin which supposedly covers the 76 Su-57s and associated setup costs.[89] This seems far too low as this would mean a unit cost of around $34 million – less than many modernised Flanker variants. As such, the $2.63 billion is likely to only cover an initial tranche – with the remainder of the 76 having to compete for stretched funding within the overall Russian military modernisation budget.

Furthermore, the Saturn Izdeliye 30 engines intended to power the production-standard Su-57 are not ready for production. So far, only a single prototype Izdeliye 30 has been flight tested on a Su-57 airframe alongside one of the lower-thrust placeholder AL-41F engines which currently power all flying pre-production airframes.[90] Great hopes had been placed on export success helping to fund development work and reduce unit costs, but so far no country has signed up. Though a long-time partner, India withdrew from its Su-57-based Fifth Generation Fighter Aircraft (FGFA) co-development programme in 2018 due to concerns about the Russian aircraft's stealth attributes, software information transfer rights and development schedule.[91] Despite rumours around either an Algerian or a Turkish deal for the aircraft, such an agreement has not yet materialised.[92] Even if all 76 airframes announced by Putin are ordered, the VKS will operate significantly fewer than 100 Su-57s by the end of the 2020s, and the likelihood that the sensors, avionics and engines will be mature is questionable without significant export successes.

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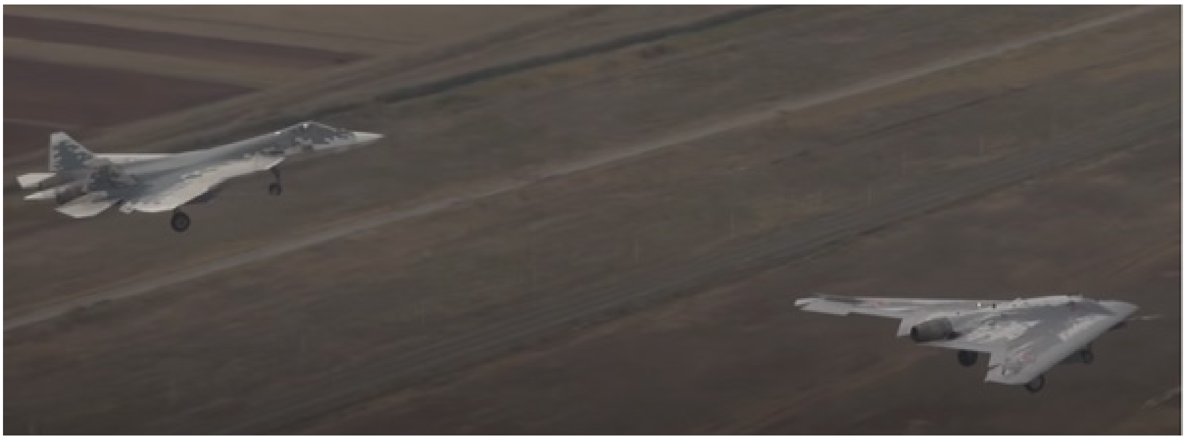
87. For details on the R-77M and K-74M2, see Butowski, *Russia's Air-Launched Weapons*, pp. 47, 52–53.
88. Joseph Trevithick, 'Russia Now Claims It Will Buy 76 Su-57 Advanced Fighter Jets By 2028', *The Warzone*, 16 May 2019.
89. *Ibid.*
90. *Ibid.*
91. Joseph Trevithick, 'It's No Surprise India Finally Ditched Its Stealth Fighter Program With Russia', *The Warzone*, 23 April 2018.
92. See, for example, *RT*, 'Turkey in "Talks" on Buying Russian Su-57 Jet Fighters – Erdogan', 30 August 2019, <https://www.rt.com/news/467624-erdogan-su57-moscow-talks/>, accessed 8 July 2020.

Besides the Su-57, the other potentially significant development in next-generation Russian combat air is the Su-70 Okhotnik-B UCAV. The Su-70 was revealed in 2019 and made a series of test flights, including one in formation, alongside a Su-57 in an apparent nod to the potential for manned–unmanned teaming tactics with the two systems.[93] Much like the UCAV demonstrators flown by the US, the UK, France and China, the Su-70 is a tailless blended wing-body design, with potential strike and ISTAR roles.

Figure 7: Sukhoi Su-70 Okhotnik-B in Formation With Su-57



Source: Russian Ministry of Defence Public Footage Capture.

There are notable features, such as the standard AL-31F series jet exhaust installation, multiple ram-air intakes and test data probes and awkward frontal jet intake, which are problematic from an all-aspect RCS perspective. Nonetheless, Sukhoi is well aware of the requirements – if not yet in a position to achieve them – to refine the Su-70 into a genuine VLO UCAV for penetrating defended airspace.[94] Furthermore, with internal weapons and sensors and a cleaned-up airframe, the basic shape is a proven LO configuration that would not take huge advances over Su-57 production techniques to achieve a significant level of LO capability. What is more questionable is how long it will take Russian industry to develop the reliable, compact avionics, datalinks and sensors needed to make the Su-70 a useful operational asset for the VKS. Having to fit all the required sensors and avionics into a clean, LO-shaped fuselage without heat, access or signal interference problems is very challenging from a manufacturing standpoint. Furthermore, to make the type useful in high-intensity combat, it would have to be able to semi-autonomously carry out combat tasks in combination with other assets under heavy ECM conditions since remote control links would not be reliable. Strike sorties against pre-planned targets or enemy emitters such as radar sites are among the mission sets which could

93. Joseph Trevithick, 'Watch Russia's S-70 Unmanned Combat Air Vehicle Fly With an Su-57 for the First Time', *The Warzone*, 27 September 2019.
94. Tyler Rogoway, 'Russia's Sukhoi Shows off Stealthier Vision for Its "Hunter" Unmanned Combat Air Vehicle', *The Warzone*, 25 August 2019.

be easier to achieve, but recent statements suggest an ambition to use the Su-70 for defensive counter-air and even OCA sorties against enemy enablers such as tankers and AWACS.[95] Russian industry has so far struggled to keep up with American or Chinese progress in terms of advanced in-flight automation, so getting the Su-70 to function reliably in combat, especially in such complex mission sets, may prove harder than fielding a credible airframe design.

Russia's long-rumoured next-generation bomber project, the PAK DA, reportedly entered the prototype production phase in May 2020.[96] However, a B-2 class bomber is an immensely complex undertaking and – as with the Su-57 and Su-70 – Russian industry will likely struggle to produce a credible VLO design within the next decade. The production of a prototype airframe is likely, but this is no guarantee of the industrial and technological capacity to actually develop an operationally credible production aircraft.

95. Ryan Pickrell, 'Russia is Talking About Giving Its Stealthy "Hunter" Drone an Air-to-Air Combat Mission as a Long-Range Interceptor', *Business Insider*, 28 August 2020.
96. *TASS*, 'Russia Begins Construction of the First PAK DA Strategic Bomber – Sources', 26 May 2020, <https://tass.com/defense/1160253>, accessed 30 September 2020.

III. Chinese Fast Jet Capabilities

THE CHINESE PEOPLE'S Liberation Army Air Force (PLAAF), along with the People's Liberation Army Naval Air Force (PLANAF), operate increasingly modern and capable fleets of fighter and attack aircraft. While the largest single fleet remains the obsolescent J-7 family of Mig-21 derived light fighters, these are being steadily replaced by the indigenously produced J-10 'Vigorous Dragon' series of multirole fast jets. Likewise, the J-8 family of interceptors and JH-7 strike/ground attack fleet are being steadily replaced by the much more capable Flanker-derived J-11B and J-16, respectively. In addition to the fast jet fleet, the PLAAF and PLANAF also operate around 200 modernised H-6 bomber/long-range missile carriers as well as a wide array of airborne early warning and control (AEW&C) aircraft, UAVs of all kinds and a limited number of H-6 tankers.[97] China is also actively pursuing UCAV technologies, with several programmes known to be underway. The composition of the Chinese fast jet inventory is laid out in Table 2.

Table 2: Combat-Capable PLAAF and PLANAF Fast Jet Types as of Early 2019

Fleet Size	Type	Role
600	J-7B/BH/E/L/G 'Fishcan'	Fighter (obsolescent)
45	J-8BH/DH/F/HF/JZ-8F 'Finback'	Interceptor/tactical reconnaissance
415	J-10A/B/C 'Vigorous Dragon'	Multirole fighter
440	J-11A/B/BS 'Flanker-L'	Air superiority
50	J-20A 'Mighty Dragon'	Heavy low-observable fighter
24	Su-35S 'Flanker-E'	Heavy multirole fighter
250	JH-7A 'Flying Leopard'	Strike/ground attack
90	J-16	Heavy multirole strike fighter
98	Su-30MKK/MK2 'Flanker-G'	Heavy multirole strike fighter
20	J-15 'Flying Shark'	Multirole carrier fighter

Sources: Rupprecht, Modern Chinese Warplanes*, pp. 45–46, 60; IISS,* The Military Balance 2020*, p. 264.*

Note: These totals are the author's best estimate based on the sources available and exclude non-combat coded aircraft assigned to training or operational test and evaluation units.

97. IISS, *The Military Balance 2020*, pp. 263–65.

Chinese Air-to-Air Weapons

Since the mid-2000s, the PLAAF has introduced two new indigenous active radar-guided missiles, the PL-12 and the PL-15, and an indigenous short-range I2R missile, the PL-10. These relatively new weapons have given China approximate parity with Western equivalents while surpassing Russian missiles. The PL-10 is comparable to the European ASRAAM and IRIS-T missiles, with superior kinematic performance to the American AIM-9X Sidewinder, and a modern imaging seeker which is highly resistant to decoys. Like the AIM-9X, ASRAAM and IRIS-T, it is helmet-mounted-sight compatible, can perform all-aspect shots at very high G-loadings and has a lock-on-after-launch capability.[98]

The PL-12 was China's first indigenous active radar missile, which entered PLAAF and PLAN service in 2005, with a very similar layout to the AIM-120 series and a seeker reportedly developed on the basis of imported Russian R-77 seeker heads.[99] Its range sits somewhere between the AIM-120B and AIM-120C5. Modified variants under testing since 2010 have included an anti-radiation seeker head, versions with improved in-flight datalinks and ECCM capabilities, the PL-12C with folding fins for internal carriage on the J-20A, and a ramjet-powered variant – the PL-12D. However, these variants do not appear to have entered service; instead, they are being used to develop the successor to the PL-12, the PL-15.

The PL-15 is a missile with a visually similar profile to the AIM-120C/D, including cropped fins for internal carriage by stealth aircraft, but is longer and wider with a small AESA radar seeker head and a dual-pulse motor giving a maximum range in the 200 km class.[100] As such, the PL-15 outranges the latest AIM-120D model and has a comparable maximum range to the Meteor, although the European weapon will likely retain a significantly larger NEZ and much better P_k at beyond 100 km due to its ramjet propulsion system.[101] It is expected to replace the PL-12 as the standard BVR armament for J-10, J-11, J-16 and J-20 fighters.[102]

China is also testing a very-long-range air-to-air missile known as the PL-X (or PL-17 in the West).[103] The PL-17 is much larger than the PL-15 at around 6 m in length, and has a low-drag profile with only small cropped rear fins for stabilisation and manoeuvring in flight to maximise range. It appears to have a multimode seeker with active radar and IR-homing capabilities and a range in the 400 km class with a very high altitude cruise phase. As such, it represents a potentially formidable weapon for hunting vulnerable tanker and ISTAR enabler aircraft at very long ranges.

98. Confirmed in author interviews with serving RAF and USAF fast jet pilots, May and July 2020.
99. Rupprecht, *Modern Chinese Warplanes*, pp. 110–11.
100. *Ibid.*, p. 111.
101. Confirmed in author interviews with serving RAF and USAF fast jet pilots, May and July 2020.
102. Rupprecht, *Modern Chinese Warplanes*, p. 111.
103. *Ibid.*, p. 112.

Figure 8: PLAAF J-16 on Take-Off Carrying Two Prototype PL-X/PL-17 Missiles

Source: Chinese internet.

Chinese Flankers

China has been a major export customer and operator of the Russian Flanker family since 1991. Having originally purchased three batches of single-seat Su-27SK air superiority fighters and twin-seat Su-27UBK trainers in the 1990s, China has been replacing the Russian airframes with its own licence-built versions of the Su-27 in the form of the J-11A and later J-11B since the early 2000s.[104] While the J-11A was largely an exercise in developing a robust domestic manufacturing capability for the Flanker, the J-11B has been significantly altered compared to its Russian equivalents. After initial quality control problems with the engines were overcome, the J-11B was placed into full-scale production in 2009 and is now one of the most numerous PLAAF and PLANAF fighters. It features: Chinese WS-10A engines; a new indigenous digital fly-by-wire system; Type 1493 multimode radar with improved range over the Russian N001VE; an internal ECM system which replaces the Russian wingtip pods; a missile-approach warning system which works in the UV as well as the IR spectrum; and provision for Chinese weapons.[105] The last point is particularly important from a Western perspective, since Chinese air-to-air missile technology has largely surpassed Russian equivalents.

104. *Ibid.*, pp. 36–37.
105. *Ibid.*, p. 38.

The J-11B also features significant weight reductions compared to the J-11A and Su-27 due to significant use of composite materials in the structure, improving the thrust-to-weight ratio. This process of composite materials replacing Russian-standard metal alloy construction has been taken further in the prototypes for the J-11D, which also features two additional weapon hardpoints, uprated WS-10IPE engines and an AESA radar. The J-11D does not appear to have entered series production yet and may be intended solely to provide the pattern for a J-11B mid-life upgrade package.[106] However, it is still entirely plausible that the J-11D replaces the J-11B on production lines in the early 2020s, and it would provide China with an indigenous single-seat Flanker variant that has significant operational advantages over Russia's Su-35S – having an AESA radar, internal EW suite and the ability to carry more, longer-reaching missiles. There is little available detail about multirole capabilities for the J-11D, but current J-11 variants have the ability to fire unguided rocket pods and drop unguided bombs. Thus far they have not, however, been seen with targeting pods or PGMs. This makes sense given the intended role of the J-11 series (and a handful of Su-35S recently purchased from Russia) in PLAAF and PLANAF service is air superiority.

As far as multirole Flankers are concerned, China operates around 100 Su-30MKKs and Su-30MK2s purchased from Russia since 1999.[107] However, these aircraft are limited to Russian weapons, although various targeting pods have reportedly been integrated to overcome PGM employment limitations.[108] As with the Su-27/J-11A, China has now developed its own, improved Su-30 derivative – the J-16. The J-16 features an AESA radar, increased use of composite materials for reduced weight, a fully digital 'glass' cockpit for both crew, compatibility with the full range of Chinese PGMs and a new targeting pod called YINGS-III which is roughly comparable to the US Sniper Pod.[109] Following its entry to service in 2015, the J-16 is expected to replace the Su-30MKK and MK2 fleets over the coming decade in both PLAAF and eventually PLANAF service, and is currently China's most capable multirole and strike aircraft. There is also a dedicated SEAD/EW variant being developed known as the J-16D, which features wingtip ESM/EW pods, a new AESA radar optimised for offensive EW operations and a new internal EW suite, which displaces the usual cannon and IRST system.[110] Armed with anti-radiation missiles and long-range air-to-air missiles for self-escort, this variant will serve a similar purpose to the US Navy's EA-18G Growler. There is also a naval J-15D variant in development, with very similar modifications for service aboard aircraft carriers with the PLANAF.[111]

Together, the J-16 and J-11D are evidence that Chinese derivatives have now surpassed Russian Flankers – with superior multirole capabilities, longer-ranged and more effective missiles and operational AESA radars. The only remaining Russian advantage is the higher-rated AL-41F

106. *Ibid.*, p. 39.
107. *Ibid.*, p. 60.
108. See, for example, GlobalSecurity.org, 'Air Force Systems', <https://www.globalsecurity.org/military/library/report/2004/04fisher/7airforcesystems.htm>, accessed 30 September 2020.
109. Rupprecht, *Modern Chinese Warplanes*, p. 58.
110. *Ibid.*, p. 59.
111. *Ibid.*

engines which power the Su-35S compared to the Chinese WS-10 series. However, the AL-41Fs exported to China as part of an order for 24 Su-35S in 2015 will likely be reverse engineered. With the rate at which Chinese engine manufacturing capabilities are developing, they are already catching up with Russian firms.[112]

The J-10: China's F-16

The Chengdu J-10 'Vigorous Dragon' is China's indigenous lightweight multirole fighter, which is a rough equivalent to the American F-16 and Saab Gripen. The design features an aerodynamically unstable canard-delta configuration for enhanced agility and has been improved at a rapid pace since its introduction to service as the J-10A in 2004. The J-10A featured a modern cockpit and avionics, with intake mounts for simultaneous carriage of a K/RKL700A ECM pod and K/JDC01A targeting and a laser-designator pod to aid in the delivery of a range of PGMs.[113] By 2008, however, the J-10B had superseded the J-10A in production, featuring a host of improvements, including a new angled PESA radar, datalink, missile-approach warning systems (MAWS), a nose-mounted passive IRST sensor and a new divertless supersonic intake (DSI) design which is lighter and significantly reduces frontal RCS. The J-10B also featured an improved cockpit layout with three full-colour multifunction displays and a larger heads-up display, helping to improve pilot situational awareness.

112. Franz-Stefan Gady, 'Russia Completes Delivery of 24 Su-35 Fighter Jets to China', *The Diplomat*, 17 April 2019.
113. Rupprecht, *Modern Chinese Warplanes*, pp. 32–33.

Figure 9: J-10Cs With Anti-Radiation Missiles, PL-10s and Laser-Guided Bombs

Source: Chinese internet.

In turn, the J-10B was superseded in production by the J-10C in 2015. The J-10C features an AESA radar and improved RWR, MAWS, satellite communications (SATCOM) and datalinks. However, the standard powerplant remains the Russian AL-31F – suggesting that the PLAAF does not yet consider the WS-10A/B to be reliable enough for single-engine fighters.[114] All J-10 variants can be equipped with up to four PL-12/15 radar-guided missiles on dual pylons, in addition to PL-10s for WVR engagements. A J-10D variant is thought to be in development with further LO features, conformal fuel tanks for increased range and other specialist features to improve SEAD and strike capabilities.[115] As such, the J-10C gives China a multirole fighter with a low price tag that can compete on an equal footing against non-fifth-generation aerial opposition, at least in technical terms. Compared to a Flanker, it presents a relatively small radar and IR/visual signature which is competitive with that of modern Western light fighters such as the F-16 or Gripen. With an AESA radar, as well as passive options which include a modern IRST, ESM/RWR/MAWS suites and integration of offboard information via datalinks, it has a better chance of competing with modern opponents in situational awareness terms. On the other hand, compared to a larger twin-engine design like a Flanker, the J-10 family will suffer in terms of range, performance at higher altitudes and especially performance penalties when flying with heavy external fuel and weapons loadouts.

114. *Ibid.*, p. 35.
115. *Ibid.*

The J-10C is comparable across most performance metrics with other single-engine multirole types offered on the international market while being significantly cheaper to acquire. Since 2019, an export variant designated the J-10CE has been marketed to international customers, and seems likely to proliferate during the 2020s as states who want cheap, effective fighters without ties to Western governments look to Beijing.[116] With an AESA radar, long-range PL-15 missiles, modern cockpit and helmet-mounted display, the J-10C and future derivatives may well become the leading near-peer aerial pacing threat for Western states during the 2020s.

The 'Mighty Dragon'

The centrepiece of the PLAAF's modernisation drive is the Chengdu J-20A 'Mighty Dragon'; a heavy twin-engine LO fighter which can be credibly described as the first non-US-made fifth-generation fighter to enter frontline service. The design incorporates many features which have been copied from the F-22 and F-35, including nose cone shaping, the electro-optical targeting system (EOTS) under the nose, and the side-mounted DSI intakes. The J-20 programme has shown major improvements in surface finish, LO features such as actuators and intakes, and general build quality in recent years. This is evident from leaked photographs and public appearances of airframes over the nine years between the type's maiden flight as a technology demonstrator in 2011 and official entry to service in 2018.[117] Moreover, despite elements taken from proven US designs, helped by targeted espionage on an industrial scale,[118] stated by Daniel Coats, former US director of national intelligence, the J-20 is no mere imitation and has several design features suggesting a carefully weighted consideration of specific Chinese capability requirements.

First, the J-20 is the largest LO fighter design currently in production or known testing, with an impressive internal fuel capacity and ability to carry up to four external fuel tanks on jettisonable underwing pylons.[119] This will allow the J-20 to act as a long-range interceptor, hunting down American tanker and big-wing ISR enabler orbits far from the mainland – a critical task if China is to keep the might of American tanker-dependent tactical airpower at arm's length in a conflict. The downside is a heavier, less agile aircraft which will be more expensive to build and operate. It also cannot compete with the extreme performance or agility of the F-22.

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116. Sebastien Roblin, 'The J-10 Fighter is China's F-16 (and Now It's for Sale)', *National Interest*, 23 November 2019.
117. See, for example, AviationIntel.com, 'The Chengdu J-20: China's Black Dragon Rises While America's Raptor Falls', 21 May 2011, <http://aviationintel.com/the-chengdu-j-20-chinas-black-dragon-rises-while-americas-raptor-falls/>, accessed 1 October 2020.
118. *National Interest*, 'China Knows All About the F-35 and F-22 (Thanks to the Data It Stole)', 10 June 2019. See also Franz-Stefan Gady, 'New Snowden Documents Reveal Chinese Behind F-35 Hack', *The Diplomat*, 27 January 2015.
119. Tyler Rogoway, 'China's J-20 Stealth Fighter Photographed Toting Massive External Fuel Tanks', *The Warzone*, 22 February 2017.

The second feature optimised for Chinese requirements rather than copied directly from US designs is the level of LO ambition. The J-20A features forward canards which are not ideal from a VLO perspective, and initial batches have been powered by Russian AL-31 series engines without LO serrated nozzles. These engines not only leave the design somewhat underpowered and likely unable to supercruise, but also increase the RCS when viewed from the rear, overhead or underneath. What China appears to have decided to pursue with the low-rate initial production batches of J-20A is a fighter with a sufficiently small RCS to be hard to detect within the background clutter of any clash relatively near China's own airspace. In such a scenario, there would be hundreds of non-LO aircraft and missile tracks in the area of operations, as well as intensive EW. The threat of J-20s with long-range PL-15 missiles operating within the background chaos would be a major headache for US planners attempting to protect critical tanker and ISR orbits within useful range of the area of operations. If China were prioritising an F-22/F-35-style capability to penetrate deep into airspace defended by other powers, the all-aspect VLO deficiencies of the current J-20A would be problematic, but within a primarily regional context it is a sensible balance of cost, design complexity and LO features.

Figure 10: Two J-20A Fighters Break Formation in 2018

Source: emperornie/Wikimedia Commons/CC BY-SA 2.0.

In terms of sensor fit, China claims that the J-20A features an AESA radar augmented by smaller side-looking AESA arrays on either side of the nose, retractable IRST in front of the cockpit, EOTS under the nose, and an F-35-inspired 360-degree EODAS.[120] Sensor output is displayed to the pilot via a fully digital glass cockpit, and a helmet-mounted display has been in service since May 2018.[121] Given the extremely close hold that the Chinese government keeps on information about the J-20, which has noticeably tightened since 2016, it is very difficult to assess the credibility of the sensor suite as claimed. However, it is clear that China has understood the importance of being able to credibly conduct air combat in predominantly passive sensor states to avoid giving away the position of LO assets, such as the J-20 in combat against the US – especially since the latter has superb ESM capabilities in both the air and maritime domains. China can also draw on highly competitive indigenous micro-electronics and programming sectors in a way that Russia cannot, as well as large quantities of stolen technical data on US programmes. The rate of iterative development, testing and production also remains extremely high, meaning that while it may be a reasonable assumption that Chengdu have not yet solved the many challenges inherent in true sensor fusion and seamless passive sensor integration, future J-20B/C variants will continue to close the technical gap with the US. In anticipation of this trend, the US has started integrating F-22 and F-35 sorties into the 'Red Air' aggressor inventory at the famous *Red Flag* warfighting exercises in Nevada in recent years, precisely to simulate the J-20B.[122] Its combination of passive sensors, AESA radar, LO features, range on internal fuel, and long-range missiles make the J-20 a qualitatively greater threat than any previous non-Western combat aircraft.

The immediate PLAAF development priority for the J-20A at this point is integrating more powerful, indigenous engines. A WS-10C powered variant has been in testing since 2018, featuring serrated LO nozzles and potentially thrust-vectoring capabilities.[123] A WS-10C powerplant with thrust vectoring appears to have formed the basis for the interim J-20B version which entered production in 2020.[124] The J-20B and J-20A may be produced in tandem until the definitive, much more powerful WS-15 engine is ready to power a putative J-20C in around 2025.[125] It is possible that the J-20C might feature deletion of the canards (and associated changes to the overall wing shape) in order to improve the LO characteristics of the aircraft. Such a change would depend on the thrust vectoring reportedly being trialled in the J-20B proving successful.

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120. Tyler Rogoway, 'High-Quality Shots of Unpainted Chinese J-20 Stealth Fighter Offer New Capability Insights', *The Warzone*, 31 July 2018. See also Rupprecht, *Modern Chinese Warplanes*, pp. 41–42.
121. Rupprecht, *Modern Chinese Warplanes*, pp. 41–42.
122. Author discussion with senior US Air Force officer, London, 29 May 2019. See also US Air Force, 'Air Force to Reactivate Aggressor Squadron for F-35 Training', 9 May 2019, <https://www.af.mil/News/Article-Display/Article/1843434/air-force-to-reactivate-aggressor-squadron-for-f-35-training/>, accessed 13 July 2020.
123. Rupprecht, *Modern Chinese Warplanes*, p. 43.
124. Jamie Hunter, 'China's Enhanced J-20B Stealth Fighter May Arrive Soon, Here's What It Could Include', *The Warzone*, 20 July 2020.
125. Gordon Arthur, 'Chinese Military Jet Engine Production Plans Exposed', *Shephard News*, 24 January 2020, <https://www.shephardmedia.com/news/air-warfare/chinese-military-jet-engine-production-plans-expos/>, accessed 13 July 2020.

Much like the F-22 in the US, the J-20 is unlikely to be available on the export market for the foreseeable future, to safeguard the PLAAF's premier air superiority asset.

The FC-31

The other known piloted LO fighter reportedly in development is the Shenyang FC-31 – a prototype twin-engine fighter of comparable dimensions and layout to the F-35. After the very basic initial prototype flew in 2012, followed by a slightly revised second airframe in 2016, the FC-31 seemed to have failed to generate enthusiasm within the PLAAF and PLANAF. However, Shenyang has continued to work on the project as a private venture and photographs of a significantly improved third prototype emerged in mid-2018.[126]

Figure 11: The Third FC-31 Prototype Airframe in Flight in Early 2018

Source: Chinese internet.

Despite external similarities to the F-35 and F-22 – including nose shape, canopy, air intakes and aerodynamic configuration – the third airframe is likely more akin to a technology demonstrator than a potential frontline competitor to the J-20A at this stage. Shenyang has attempted to market the type as a potential export fighter,[127] and discussions persist around

126. David Axe, 'The Chinese Navy Could Save the Stealth Fighter No One Else Wants', *Forbes*, 12 July 2020.
127. Liu Xuanzun, 'China's FC-31 Fighter Jet Shows Major Upgrades at Paris Air Show', *Global Times*, 19 June 2019.

potential adaptation of the design for use on future Chinese aircraft carriers by the PLANAF.[128] However, at present there are no confirmed orders for the type and the relative success of the J-20A suggests that the PLAAF and possibly the PLANAF may have more promising uses for the large-scale resources required to develop the FC-31 into a viable operational capability in the near to medium term.

Exotic Projects: UCAVs, Counter-Stealth UAVs and New Bombers

China is an enthusiastic developer of UCAVs, with at least three different potential programmes which have been leaked or acknowledged in the public domain. The most advanced is the GJ-11, also known as 'Sharp Sword', which has been in flight testing since November 2013.[129] The GJ-11 is a VLO flying wing design, a configuration which has been used for a number of US and European UCAV technology demonstrators, as well as the Russian Su-70. GJ stands for *gongji* (attack), which suggests a penetrating strike as well as possibly ISTAR role. A more refined and stealthier version was shown off in the Chinese Communist Party's (CCP) 70th anniversary parade in October 2019, suggesting development is ongoing.[130] It is reportedly intended to carry two 2,000-lb-class weapons in internal bays, and is set to be equipped with a buried SATCOM antenna within the airframe.[131] Despite SATCOM capabilities, however, operating in heavy EW conditions – such as those likely to be encountered in any conflict with the US or other regional powers like Japan – would require significant levels of in-flight autonomy, including the ability to release weapons on targets without real-time human control. This is one of the reasons why UCAV development has not been publicly undertaken beyond technology demonstrators in the US or Europe. It is unlikely, however, that the Chinese government would perceive the ethical and legal implications of lethal autonomy in the same way as some Western states do.

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128. *Navy Recognition*, 'Chinese FC-31 Stealth Fighter to Possibly Enter Service in the PLA Navy', 8 June 2020, <https://www.navyrecognition.com/index.php/news/defence-news/2020/june/8562-chinese-fc-31-stealth-fighter-to-possibly-enter-service-in-the-pla-navy.html>, accessed 21 July 2020.
129. Jeffrey Lin and P W Singer, 'Meet China's Sharp Sword, a Stealth Drone That Can Likely Carry 2 Tons of Bombs', *Popular Science*, 18 January 2017, <https://www.popsci.com/china-sharp-sword-lijian-stealth-drone/>, accessed 31 July 2020.
130. Joseph Trevithick, 'China Showcases Stealthier Sharp Sword Unmanned Combat Air Vehicle Configuration', *The Warzone*, 1 October 2019.
131. Rupprecht, *Modern Chinese Warplanes*, p. 105.

Figure 12: Leaked Photograph of Initial GJ-11 Prototype During Flight Testing

Source: Chinese internet.

Other potential Chinese UCAV projects include the Dark Sword supersonic loyal wingman,[132] which was teased in full-scale mock-up form in 2018, the CH-7 advertised for export at the 2018 Zhuhai airshow, and the shadowy WZ-3000/CH-X which reportedly first flew in 2012.[133] These platforms offer a potential route for China to play to its strengths – massive industrial capacity and a willingness to invest heavily in radical capability development. UCAVs do not rely on well-trained and highly experienced aircrew to perform at peak combat efficiency. This may well leave them at a disadvantage if forced to directly confront piloted combat aircraft in comparable numbers, but it does mean that the limitations on the potential size and rapid growth potential of a force are not pilot dependent. This may increase their attractiveness to the PLAAF, which continues to struggle (despite impressive reforms) with matching the dynamic and realistic training given to aircrew in adversary air forces due to its inflexible organisational structure and adherence to centralised planning and tactical command practices.[134]

132. 'Loyal wingman' refers to a concept whereby UCAVs would operate closely alongside piloted fighters under their tactical control, improving the resilience, firepower and flexibility of the combined formation compared to a purely piloted or purely UCAV formation.
133. Rupprecht, *Modern Chinese Warplanes*, p. 105. See also Trevithick, 'China Showcases Stealthier Sharp Sword Unmanned Combat Air Vehicle Configuration'.
134. For more detail about Chinese training and exercise reform efforts and progress, see Rupprecht, *Modern Chinese Warplanes*, pp. 130–35. See also Edmund J Burke et al., *Assessing the Training and Operational Proficiency of China's Aerospace Forces: Selections from the Inaugural Conference of the China Aerospace Studies Institute (CASI)* (Santa Monica, CA: RAND Corporation, 2016), pp. 31–62.

In terms of other UAVs designed for peer conflict, the PLAAF has fielded two other potentially significant types in recent years. The first is the WZ-8 supersonic ISR UAV which is a rocket-powered aircraft designed to be launched from a H-6 bomber to perform rapid surveillance of areas in contested airspace.[135] The appearance of the WZ-8 alongside more conventional VLO subsonic flying wing designs, such as the GJ-11 and CH-X, shows that the PLAAF is pursuing multiple developmental avenues towards fielding robust penetrating ISTAR capabilities, which have been a uniquely American capability for several decades. These systems will contribute to increasing the robustness of the kill chain required to guide China's extensive long-range ballistic missile and cruise missile arsenal to key targets in the first island chain and eventually beyond.

The second, and perhaps even more significant, is the 'Divine Eagle' high-altitude, long-endurance (HALE) class heavy UAV which has been in testing since 2015.[136] The Divine Eagle is a twin-fuselage, turbofan-powered UAV in the same class as the RQ-4 Global Hawk, designed primarily to provide a HALE perch for a multi-static long-wavelength radar array. While a single VHF, metre-band radar is likely to struggle to generate high-quality track information on VLO aircraft, several arrays mounted on UAVs in widely spaced orbits offer much better prospects for target-grade tracking by fusing and cross-referencing each array's viewpoint into a single picture. In conjunction with ground-, space-, maritime- and AEW&C aircraft-based radars, the Divine Eagle is evidence of innovative and multifaceted Chinese work to try and unmask US-made VLO aircraft during the 2020s. While some of the approaches being taken will fail to generate significant breakthroughs in terms of situational awareness against VLO types, others will inevitably produce useful capabilities during the next decade.

Another exotic type thought to be in the prototype phase is the H-20 (V)LO bomber aircraft being developed by Xi'an as a rough analogue to the American B-2 Spirit and upcoming B-21 Raider. No credible images of H-20 prototype airframes have been released despite a slew of fakes.[137] In order to meet the range and (V)LO requirements for such an aircraft, the Xi'an Aircraft Industrial Corporation rumoured to be in charge of the design has most likely chosen a large subsonic flying wing or possible cranked kite shape. There are also significant questions around China's ability to produce engines with the dry thrust capacity for a true B-2 class aircraft. However, with a first flight rumoured to be due in the early 2020s, the H-20 seems to be fairly far along in development terms. Armed with nuclear and conventional standoff missiles, the H-20 would represent a major break from previous PLAAF doctrine and equipment development practice. The PLAAF (and PLAN) are currently configured as regional forces for a conflict within the first island chain with additional specific capabilities aimed at neutralising or supressing the US base at Guam. The H-20, by contrast, would give China a truly intercontinental power-projection capability.

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135. Tyler Rogoway, 'China's High-Speed Drone is Rocket-Powered and All About Doing What Satellites Can't', *The Warzone*, 1 October 2019.
136. Rupprecht, *Modern Chinese Warplanes*, p. 104.
137. For more details, see Joseph Trevithick, 'China Teases Its H-20 Stealth Bomber and Trolls Northrop Grumman at the Same Time', *The Warzone*, 8 May 2018.

In addition to the long-range H-20, the US Defense Intelligence Agency's 2019 report on China also highlighted another next-generation LO bomber project underway – the medium-range J/H-XX.[138] Unlike the subsonic flying wing/cranked kite Xi'an H-20, the J/H-XX is thought to be a supersonic fighter bomber under development by fighter-manufacturer Shenyang, with LO features including internal weapons carriage and a weight and role similar to the now-retired American F-111 Aardvark.[139] Alongside the J-20B/C, the J/H-XX is likely to give the PLAAF of the late 2020s an impressive penetrating OCA and strike capability in contested airspace – especially against the key bases, such as those on Guam and Okinawa, as well as potentially against naval assets.[140] Since the US abandoned a longer-range strike-focused derivative of the F-22 or XF-23 in the 2000s, the J/H-XX is also an unusual example of a modern combat aircraft concept ideally suited to combat in the vast distances of the Indo-Pacific, in stark contrast to many shorter-ranged Western designs.

138. Defense Intelligence Agency, 'China Military Power: Modernizing a Force to Fight and Win', 2019.
139. *Defence Aviation Post*, 'The JH-XX Stealth Bomber is China's Worst Kept Military Secret', 7 May 2020, <https://www.defenceaviationpost.com/2020/05/the-jh-xx-stealth-bomber-is-chinas-worst-kept-military-secret/>, accessed 16 July 2020.
140. Tyler Rogoway and Joseph Trevithick, 'Intel Report Confirms China Developing Stealthy Tactical Bomber in Addition to Strategic Bomber', *The Warzone*, 16 January 2019.

Conclusion: Russian and Chinese Air Threat Nature and Trajectories in Perspective

RUSSIA AND CHINA currently field combat air fleets that are similar in many ways, at least at face value. Both rely heavily on the Flanker family of combat aircraft and their various derivatives; both have attempted to develop a fighter with LO features; and both have sought increasing multirole capability for their fighter fleets as a whole. However, China has started to build a clear technical lead over Russia in most aspects of combat aircraft development. Moreover, Russian industry is unlikely to be able to regain areas of competitive advantage once lost, due to deep structural industrial and budgetary disadvantages compared to the Chinese sector.

The effects of this trend can be seen in the fact that even in the case of the archetypal Russian fighter line, the Flanker, the most capable variant currently in service is Chinese. Compared to Russian equivalents, the J-16 features a more modern cockpit layout, more advanced use of structural composites, access to more advanced and longer-ranged missiles, an AESA radar and operational targeting pods for more efficient and flexible employment of modern PGMs. The only area where Russia retains a lead in Flanker development terms is in engines, with the AL-41F series powering the Su-35S still providing superior thrust and reliability compared to the WS-10B series. In terms of cheaper and lighter multirole fighter types, the J-10C is significantly more efficient and flexible than the ageing Russian Mig-29/35 series. In contrast to the troubled Russian Su-57, with its limited LO features and production prospects, the Chinese J-20A is an operational LO fighter already in squadron service with the PLAAF. It also continues to rapidly mature and improve with the production of the J-20B variant having reportedly begun in 2020.[141] The J-20 family will be produced in the hundreds over the coming decade, constituting the foremost existing aerial threat to Western air superiority types.

Beyond simple comparisons of individual aircraft categories, there is a noticeable difference between the developmental focus for Russian and Chinese combat air concepts of operation and tactics. In broad terms, Russia continues to try and field more powerful fighter radars and develop longer-range air-to-air missiles to redress its current shortcomings in relation to existing non-VLO opponents, while counting largely on long-range ground-based sensors and missile systems to provide a measure of national defensive capability against VLO threats, including some distance beyond its own borders.[142] By contrast, China is prioritising the development

141. Hunter, 'China's Enhanced J-20B Stealth Fighter May Arrive Soon, Here's What It Could Include'.
142. For in-depth discussions of each country's approach to ground-based IADS capabilities, see Bronk, 'Modern Russian and Chinese Integrated Air Defence Systems'.

of aerial sensors and networks to allow its combat aircraft to compete directly with the US in engagements beyond its own borders that are dominated by passive-sensor tactics and cooperative engagement capabilities. The PLAAF is being rapidly configured for power-projection capabilities at scale, with ground-based and maritime IADS elements serving as an important but not dominant component in the country's approach to airpower. Above all else, the pace of iterative improvement visible in PLAAF equipment – from aircraft and weapons systems to increasingly realistic training and exercises – is striking. Aside from the PL-15 (and PL-X/PL-17) very-long-range air-to-air missile, there are few areas of capability where the PLAAF is yet directly able to compete one-to-one with the best that the US and European air forces can field. However, if China can continue the level of investment, production and iteration demonstrated over the last decade, then existing capability gaps will close significantly, and more areas of outright Chinese advantage will emerge during the 2020s.

For the US and its Indo-Pacific allies, this is a serious military challenge, but it also has significant implications for air forces around the world that are unlikely to have to directly confront the PLAAF or PLANAF. As the superiority of Chinese weapons systems and airframe manufacturing capacity over Russian equivalents becomes increasingly obvious, countries with political alignments or budgets that preclude relying on Western aircraft will look increasingly to Beijing rather than Moscow for equipment, especially as Soviet-era fleets continue to age out. In other words, the high-end aerial pacing threats for Western air forces in a near-peer conflict or expeditionary intervention context are likely to be Chinese by the end of the 2020s. Of course, much like Western and Russian types, Chinese combat aircraft and weapons will usually be supplied to most third countries in slightly degraded export configurations, especially with regard to EW, encrypted communications, radar and seeker performance.

In technical terms, PLAAF and PLANAF combat aircraft are also operating alongside an increasingly diverse and capable set of ISTAR enablers, including three different traditional AEW&C platforms, multiple classes of UAVs, maritime and ground-based sensor arrays, and orbital constellations. Modern Link 16-style datalinks are also increasingly standard on Chinese fourth- and fifth-generation combat aircraft and supporting enabler platforms.[143] However, this potential force multiplying advantage is currently limited by a lack of operational experience and inflexible internal structures, but the pace of Chinese improvement is rapid in these areas. If being operated by smaller states, many of these enablers would not be available, or at least would be far less extensive, rendering Chinese fast jets correspondingly less impressive compared to Russian types and less of a threat to well-supported Western fast jets as part of a coalition. They would nonetheless significantly increase the risk profile and capability requirements for an intervention compared to Soviet-era capabilities, especially if operated in conjunction with increasingly widely proliferating Chinese or Russian ground-based air defences and EW systems.[144]

143. Author interview with Defence Science and Technology Laboratory Chinese and Russian equipment subject matter expert, July 2020.

144. For more information, see Bronk, 'Modern Russian and Chinese Integrated Air Defence Systems'.

The PLA itself currently struggles to conduct genuinely joint operations, as the PLAAF and broader PLA remain highly stovepiped and procedural organisations compared to their Western counterparts. For example, combat air training is still predominantly conducted according to rigidly pre-briefed manoeuvre sequences under direct control of a ground- or AEW&C aircraft-based commanding officer, with lessons or tactical innovations having to go through a lengthy bureaucratic process to be formally incorporated.[145] The PLA also remains unable to operate joint engagement zones, which are required to enable SAMs and combat aircraft to engage targets in the same airspace simultaneously.[146] Nonetheless, there is significant evidence of rapid improvements to the realism of training, including increasing prevalence of unscripted air combat engagements during the 'Golden Helmet' competition and *Red Sword* and *Blue Sword* exercises since 2011, as well as recent joint training exercises with other air forces including those of Russia, Pakistan and Thailand.[147] The result is rapidly improving operational competence within each of the Chinese air arms, and a slow but steady improvement in the PLA's ability to conduct joint warfighting as a whole. Chinese airpower may be less impressive in practical warfighting capacity than its equipment would suggest on paper, but the ingredients for continued rapid capability growth are all in place, and at a scale that few competitors will be able to keep pace with. The implications are serious enough for the US Air Force and US Navy, which have traditionally relied on a significant level of qualitative overmatch to offset Chinese numerical superiority in the Pacific theatre.[148] They have even more significant implications for China's less militarily capable neighbours looking to maintain an ability to defend their territorial integrity in the face of Chinese pressure.

By contrast, Russia's combat aircraft development has failed to keep pace with the cutting edge of Western or Chinese capabilities since the end of the Cold War. Annual flying hours for VKS pilots also remain low, with the average of 120 flown by the elite aggressors of the 116 UTsBPr IA representing the highest of any unit by a considerable margin, meaning advanced situational awareness building, sensor and weapon employment skills will be lacking compared to most potential NATO opponents.[149] Despite impressive work to squeeze the maximum performance out of the Su-27 Flanker airframe across multiple mission sets within the bounds of Russia's financial and technological means, Russian frontline fighters remain likely to be out-detected and outranged by the latest Western and Chinese competitors. The Su-57 is neither sufficiently LO nor sufficiently mature in terms of sensor package to be considered a major threat to the West's qualitative advantage in the air superiority domain at this point. However, it could still present a serious potential threat to older fourth-generation fighters if introduced into service in significant numbers. Russia's primary means to defend its own airspace and project contested airspace into its near abroad remains its ground-based IADS.[150] The VKS's primary tactical missions

145. Author interview with Ken Allen, CASI, Washington, DC, 22 February 2019.
146. *Ibid.*
147. Rupprecht, *Modern Chinese Warplanes*, p. 133.
148. See, for example, Aaron Mehta, 'Inside US Indo-Pacific Command's $20 Billion Wish List to Deter China – And Why Congress May Approve It', *Defense News*, 2 April 2020.
149. Butowski, *Flashpoint Russia*, p. 33.
150. For more details, see Bronk, 'Modern Russian and Chinese Integrated Air Defence Systems'.

in the case of a conflict with NATO are likely to be defensive patrols contributing overhead radar information and potentially missile shots to the broader IADS, alongside strike missions against enemy ground and maritime targets within or close to the coverage of mobile ground-based SAMs using standoff munitions wherever possible. In that strike mission, however, the majority of VKS pilots have fairly recent combat experience in a relatively complex semi-permissive environment thanks to regular unit and personnel rotations to Syria since 2015.

Without having first significantly degraded Russia's IADS, NATO air forces would likely struggle to exploit many of the areas of technical advantage their platforms have against Russian aircraft operating close to their own airspace. As such, the VKS poses a potent threat against any NATO static ground-based assets not protected by layered ground-based air defences or friendly defensive counter-air patrols. Against dynamic battlefield targets such as moving vehicles, however, the lack of operational targeting pods in Russia's multirole fighter fleets would limit their effectiveness, leaving the VKS to rely on its Su-25, Su-24M and Su-34 fleets alongside rotary wing aviation and substantial ground forces firepower for this task. Despite being outclassed by the latest Western and Chinese types, the Russian Flanker series remains a potent air-to-air threat against any combat aircraft lacking up-to-date active and passive sensor suites and either VLO characteristics or missiles capable of outranging the R-77-1 series.

One contingency worth considering is the possibility that, at some point during the 2020s, Russia begins to import Chinese missile or sensor technology for use by the VKS. For this to occur, the Russian government would have to overcome considerable levels of distrust between Russia and China in military terms, as well as deep-seated Russian pride and attachment to their sovereign aerospace industry. However, the increasing superiority of Chinese radars, AAMs and targeting pods may prove sufficient motivation, especially in the face of a new generation of Western combat aircraft development programmes. Full-scale Russian manufacture of Chinese indigenous designs such as the J-20 or J-10 would likely be too bitter a pill to swallow, but the integration of Chinese sensors and weapons on Russian Flankers or even as part of efforts to mature the Su-57 and/or Su-70 would undoubtedly improve their combat capabilities. Whether China would agree to exports or technology transfer of this level to Russia is another question entirely, and one which is difficult to answer. However, if tensions between China and the West continue to rise and Russia remains confrontational towards NATO in Europe and the Arctic, then the CCP may decide that subsidising Russian military capabilities is in its interests.

About the Author

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