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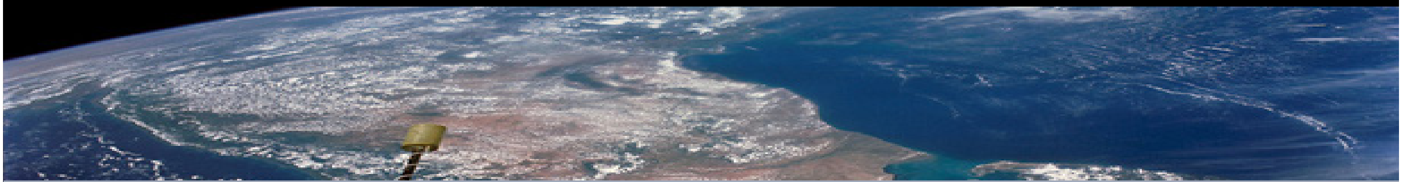

Air Force Day 2025 | The Warriors Soaring the Blue Skies Business Line

Source: https://www.thehindu.com/children/air-force-day-2025-the-warriors-soaring-the-blue-skies/article70133917.ece

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"AIR FORCE DAY PARADE 2025 was a befitting tribute to IAF's ninety-three years of unwavering dedication and unparalleled service to the nation, embodying the theme of – 'Indian Air Force: Infallible, Impervious and Precise."

PIB, Delhi

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Move With Caution

Air Vice Marshal Anil Golani | Director General, Centre for Aerospace Power and Strategic Studies | October 2025

[Source: Force | https://forceindia.net/blog/move-with-caution](https://forceindia.net/blog/move-with-caution)

The debate on jointness, integration and theatre commands continues unabated as there seems to be a lack of a roadmap towards achieving the goal of desired synergy between the services. While a few steps have been taken and many comparisons made with other countries that have already trodden down this path, there is a need to have a clear understanding of the terminology and desired outcomes. The peculiar nature of the threats that India as a country is faced with and its culture and ethos also needs to be not only understood but also taken cognisance of while embarking on this journey. The recent face-off with Pakistan, 'Op Sindoor' was prescient in many ways and probably happened at an opportune moment for India to learn the right lessons going forward.

Jointness and integration have often been used interchangeably. Jointness refers to the synergistic application of force with the aim of combining the strengths of each service/ arm to produce greater effect and avoid duplication. Each service would retain its independent identity and structure while operating through a decision-making structure that involves coordination and consensus with the forces operating together to achieve a common goal.

Integration, on the other hand, would require the forces to be structurally combined under a multi-service command, merging the identities of the services into a composite whole. The authority in this case would vest with a single commander who must fully understand the working of the merged services to employ them effectively across domains. Jointness, as can be seen, is the first step towards integration.

Theatre, on the other hand, refers to a specific geographical area or operational theatre where the individual services are unified under a single operational commander. Andaman and Nicobar Command (ANC) is an example of a theatre command where the forces are unified under a single operational commander. As can be seen, jointness is the first step towards integration. To achieve operational jointness, organisational jointness would therefore be a prerequisite. At the same time individual service culture, ethos and warfighting skills need to be not only preserved but continually honed to greater effect. A joint culture or ethos, though desirable may not be practicable.

India faces a two-front challenge that

acts in collusion and is unlikely to either go away or get resolved in the foreseeable future. Geopolitical contestation, failure of the rules-based world order, tariff wars and technology denial regimes only add to India's woes. The journey and challenge of self-reliance or 'aatmanirbharta' that the nation has embarked upon is going to be long and arduous, though beneficial in the long term. The changing character of war that spreads across multiple domains and where anything can be weaponised as witnessed by recent and ongoing conflicts, only adds to the complexities.

Against this backdrop and scenario any disruptive change may not augur well for national security. A bottoms-up approach that is graduated in its response and outcomes needs to be followed. Secure and common communication, joint training, logistics, professional military education, human resource management and policies, joint doctrines, armed forces law and joint capability development are some of the measures that have already been initiated since the creation of the CDS and DMA in 2019. These would take time to fructify and seep into the individual services and is a process that needs to be pursued relentlessly. The need for jointness and integration is felt acutely when faced with a crisis. The fact that India's armed forces have risen to the challenge and ensured national security every time is reassuring no doubt. However, future wars would demand much more and the only way to counter these threats would demand the services to be well equipped, trained and organised to meet the challenges.

Operational planning and command and control presently is being done separately by each service except for the strategic forces and the ANC. Joint structures for cyber, space and special forces have been created and are working effectively. Modern wars require not only integrated use of force across multiple domains but a whole of nation approach to counter perceptions in the cognitive domain as well. This fact is not only understood but also accepted by the armed forces leadership. What then is the way out?

Creation of a joint operational planning structure at the apex level where political objectives and decision-making merge seamlessly should be the starting point. This was created on the fly after the Pahalgam terror attack and worked effectively ensuring the unparalleled success of 'Op Sindoor.' A detailed and deliberate analysis of this should lead to the creation of an organisational structure that would respond to future threats.

India's geography and its neighbourhood pose multifaceted challenges that would require its armed forces to keep the powder dry for future wars. To continuously adapt, reform, transform and perform is the key that would ensure national security. This is a fact that is well understood by the senior leadership of the armed forces, and many steps have been initiated towards transformation. The cup may appear half full or half empty, but what needs to be kept in mind is national interest and national security above parochial service interests. The choice of weapon or instrument of force should bear allegiance to national security over ownership by any single service.

Solving the Indian Air Force's Fighter Dilemma

Amit Gupta | October 2025

[Source: Geopolitics | https://geopolitics.in/oct2025issue.aspx](https://geopolitics.in/oct2025issue.aspx)

(File picture) 30 out of the 32 Tejas Mk-1 has been inducted into the Indian Air Force

The Indian Air Force has begun eThe dilemmas facing the Indian Air Force (IAF) fighter force are well known: the IAF T is meant to be at 42 combat squadrons but is around 31 and facing a two-front threat, international aircraft production has met with lengthy delays leading to a medium to long term shortfall of aircraft; the country's arms acquisition process is lengthy and cumbersome; even if deals were signed expeditiously, it will be years before new fighters enter squadron service; and domestic aircraft production has encountered its own set of problems that need to be resolved. The question is what can and should be done to reverse these trends.

Numbers Matter

The Russians say that quantity has its own quality, meaning that if you have a large number of aircraft, it gives you force superiority and redundancy in the ability to take losses and continue the fight. Recognising that the country now has a two-front threat with China and Pakistan, and the fact that both its adversaries are rapidly modernising, the IAF has made informal plans to eventually build the force up to sixty combat squadrons. That would mean doubling the current force to over 1,000 combat aircraft.

The problem for the IAF is that it will not be easy to even get back to 42 squadrons. The reason for this is the global problem of continuing delays in production and the existing commitments of fighter manufacturers. For example, Lockheed Martin has orders to sell 167 F-16s around the world, and last year it delivered 16 aircraft to its customers. That would mean if India were to sign a deal tomorrow for the F-16, which, given India's cumbersome acquisition process, is unlikely, it would still be around eight to ten years before the first aircraft came into the Indian force structure.

Similarly, Dassault Aviation delivered 21 Rafales in 2024, of which 14 went to the French military and 7 were for exports (incidentally, this was up from the 13 delivered in 2023). Dassault, by its own admission, has a backlog of 200 aircraft to deliver, which, given its production rates, would mean another eight to ten years before a delivery could be made to a new customer.

There are a number of reasons for these delays. COVID-19 slowed down the production of aircraft and their power-plants and associated systems, leading General Electric to be unable to provide engines for the Tejas Mk. la. The problem for all countries is that while they seek to modernise their forces, the industrial capability is lacking to give timely deliveries to customers. Aircraft have become technologically complex, and making them is a time-consuming and lengthy process.

Worse, India's domestic manufacture of the Tejas has been met with sanctions, production delays, quality control problems, and production inefficiencies. Thus, while the Tejas was ordered in 2006, the first Tejas was delivered in 2016, and the IAF's Chief Air Marshall A.P Singh pointed out that by 2025, Hindustan Aeronautics Limited had yet to complete the original order of 40 aircraft. This made a mockery of HAL's claim that it could make eight aircraft a year and eventually ramp up annual production to sixteen planes.

The production delays are a double-edged sword since aircraft technology has moved beyond the Tejas, and both Pakistan and China are acquiring fifth-generation aircraft, with Beijing likely to acquire sixth-generation fighters possibly by the end of the decade. So not only is the IAF getting an obsolescent plane, but it is getting them in small numbers. If the plane was supplied quickly to boost up squadron strength, it could still be useful to fulfil the IAF's missions.

The way to do that is actually to hold HAL's feet to the fire and make it clear that if it does not deliver sixteen aircraft as it has promised, it will be heavily penalised by the government. These aeroplanes can be used as part of a high-low mix in that they could provide the numbers and be kept in a secondary role. After the frontline fighter-Rafales and Sukhois-inflict. the initial damage to the adversaries, the Tejas could be used to carry out secondary missions.

The other way to salvage the Tejas is to use the lead time that HAL. will have for embarking on the Mark 2 version of the aircraft and put a better radar in it, and mate it with India's new range of missiles, particularly the Brahmos and Astra, as well as any air-to-ground ordnance that has been indigenously produced. That way, the aircraft becomes a "missile truck that can deliver missiles and ordnance from beyond visual range and complicate the mission of the enemy. While Tejas fulfils nationalistic aspirations and creates domestic employment, what is needed, however, is a new generation of imported fighters, and to understand the requirement, one must assess the potential acquisitions by Pakistan and China.

Fighter Aircraft Options

Operation Sindoor revealed that India would have to spend substantially to not. only counter the Chinese but also the PAF because Pakistani press reports are suggesting that by the end of 2025, the PAF will get the J-35 stealth fighter, which is a true fifth-generation fighter. One should take this statement with a grain of salt since Pakistan is unlikely to get the aircraft in meaningful numbers to make a difference to the balance of forces with India. Both the Chinese Air Force and Navy have an urgent need to induct these aircraft in significant numbers because they are worried about what Donald Trump may do to support calls for Taiwanese independence and, as a consequence, want to rapidly induct modern weaponry into their force structures.

As things stand, the PLAAF still has over 300 J-7 and J-8 legacy fighters (which are

Chinese versions of the venerable MiG-21) while the rest of the fleet is a mix of more modern fifth-generation J-20s (300 plus) as well as over 1,000 variants of the Su-27 and the Su-30. Replacing the legacy fighters with the advanced J-35s will take several years to complete. So, while there may be a commitment to sell the J-35 to Pakistan, it is most likely that the PAF gets maybe one or two J-35s to familiarise itself with the plane, and deliveries will begin much later.

Nor is it clear whether Pakistan can even afford the aircraft in sizable numbers. China, despite claims to the contrary, charges Pakistan for the aircraft it sells, although the planes are sold at a "friendship price to the PAE The JF-17, for example, was initially priced at around $35 million but was sold to the PAF at the "friendship price" of $26 million. Its fleet of 36 1-10 was reportedly bought in a $1.4 billion deal that also included 250 PL-15 missiles. This figure seems low since the PAF would also have had to purchase all the support systems for these aircraft, and that would almost certainly drive up the cost of procurement. So yes, the PAF will get more fighters, but it is unlikely that Beijing will put Islamabad's purchases on a fast track given its own need to modernise the PLAAE.

What is more likely in the short term is that Pakistan will get additional J-10s and JF-17s, with the Chinese possibly upgrading the missile capability of the 1-10 by providing the more modern J-17 air-to-air missile to Islamabad. On the other hand, India should expect to face a PLAAF that is moving quite quickly up the modernisation ladder. For India, therefore, the need is to be proactive and buy more fighters while planning for a sixth-generation plane. To do so, it will have to bring about several reforms as well as take proactive steps in the acquisition of new aircraft.

First, the government has to to get over its slow and cumbersome acquisition process and recognise that the IAF urgently needs new aircraft. Long negotiations, constant price haggling, and shrinking the purchase (as was the case with the original Rafale deal, which was reduced because of price pressures from 126 to 36 aircraft) are no longer acceptable in a worsening threat environment.

Second, any purchase must make a significant strategic difference. When the original Rafale deal went through, there was a lot of hype in the national media about how it was a game-changer. This implied that it equalised the air equation with China and provided air superiority over Pakistan. The Chinese, however, pointed out that 36 Rafales would make very little difference along the long India-China border and that far more aircraft would be needed to ensure air superiority for the IAF air Similarly, against Pakistan, superiority means a numerical ratio of 2:1 in favour of the attacker and India right now does not have that against the PAR Put simply, any future purchases have to be where numbers matter rather than the piecemeal deal that the Rafale was.

The first order of business, therefore, is to buy over one hundred Rafale under the Medium Range Fighter Aircraft program. The Air Force has now made this decision, and the government has to conclude the deal expeditiously. The more you delay, not only does the price go up (there is something called inflation), but the longer you also have to wait to acquire your first set of aircraft. As of December 2024, Dassault had a backlog of 211 Rafales that it has to clear, and at a current production rate of 21 a year, India would see its first Rafales in the mid-2030s. Yet the IAF needs the aircraft post-haste.

Secondly, the longer one waits to ink the deal, the more expensive the plane becomes. Uninformed media and government sources go on about how they are paying much more for the naval Rafale, but it has been nearly a decade since the first deal was consummated. Have car prices in India remained at the same level as in 2015? Delays, therefore, mean that inflationary trends will drive up the cost of the planes.

Apart from buying the plane, it makes sense to invest in a production line for the Meteor missile since, in the future, that will be the main weapon of the Rafale, and it could be paired with the Tejas Mark 2. The other priorities for the IAF are to invest in fifth-generation and sixth-generation fighters.

Around the world, nations are investing in the development of sixth-generation fighter aircraft that are likely to take to the skies in the late 2030s to early 2040s. These planes will be qualitatively different from their predecessors, and not investing in this capability would put India at a disadvantage situation because China has already built two sixth-generation aircraft, the J-36 and the J-50. The United States has a sixth-generation programme going, Britain has partnered with Japan for one, France has a joint program with Germany, and South Korea is designing an aircraft a well. In the meantime, India has yet to cross the threshold to a fifth-generation fighter, while Turkey, whose aerospace industry started long after India's did, already has an ongoing programme called KAAN. India, therefore, needs a fifth and sixth-generation fighter project to complement the Rafale acquisitions.

There are three options for the fifth-generation aircraft, and none of them look particularly enticing for the IAF Earlier this year, Donald Trump said, Starting this year, we will be increasing military sales to India by many billions of dollars. We are also paving the way to ultimately (emphasis added) provide India with the F35, Stealth fighters..." The Indian media did not understand what Trump was saying and mistakenly concluded that the United States had offered the F-35 to India. Government officials and military officials similarly played into the misunderstanding to make it look like the India-US relationship was strong and that New Delhi had options in weapons procurement.

In fact, what Trump was saying was that India would buy military equipment from the United States and, eventually, probably a decade down the line, purchase the F-35. The United States government's plan since the Obama Administration has been to sell the F-16 to India and license the production of the plane in the country. Once India had manufactured a hundred-odd planes, then there possibly would be a shift to an F-35 production line. But it would not happen anytime in the near future.

Those hyping the F-35 Lightning fighter should remember that Lockheed already has orders pending for over 3,500 aircraft from the US military, NATO allies, and Israel. All these countries will get precedence over India, which will not be moved ahead in the queue to acquire aircraft. Lockheed is aiming to produce 170-190 aircraft in 2025, which is impressive. But even at such high production rates, it would be close to 2040 before India saw its first F-35s. That means that the Indian Air Force's chronic shortage of aircraft would continue in a worsening two-front threat environment.

As for the F-16, CQ Brown, the former U.S. Air Force Chief, made it clear that the USAF would not buy the aircraft and wanted a replacement for it. In his words, he wanted a "clean sheet design" for a new "four-and-a-half-gen or fifth-gen-minus fighter to replace the F-16, Brown elaborated. Rather than simply buy new F-16s, he said, "I want to be able to build something new and different, that's not the F-16 that has some of those capabilities, but gets there faster and uses some of our digital approach." In other words, the IAF is being offered a plane that the USAF now considers unsuitable for its future combat requirements. What then can be bought as a fifth-generation plane?

AMCA or Su-577

India has two alternatives: one is the indigenously produced AMCA; the other is to procure one from abroad. AMCA would work if there were realistic parameters attached to the production of the aircraft. The decision to work with Safran on an engine is a good one since the French are reliable partners and will give HAL an engine that satisfies the requirements of the AMCA.

What the government needs to do is act as the enforcer in any agreement between HAL. and the IAF, and do the following things. First, lock down the design and do not allow the IAF to ask for changes that lead to delays. Secondly, ask HAL what a realistic production rate is and not an optimistic estimate, as they gave in the case of Tejas. The fact is that the IAF received its first Tejas in 2016, and in the nine years since, the IAF has received fewer than forty aircraft. That means HAL has never reached its stated objective of producing eight aircraft For AMCA, therefore, the government needs to tell HAL that instead of making grandiose plans, it should say what it can actually produce, when it can deliver those planes, and how many will be produced annually. That would be moving away from the Indian production culture of technological failures and exaggerated claims. per year.

Thirdly, the IAF needs to stop asking for increasingly complicated and time-consuming additions, as it did on Tejas, and instead pursue what the Chinese call the "dumpling strategy of arms production. The Chinese argue that much in the way the first batch of dumplings is never of the best quality because the water has not reached the proper boiling point, the first weapons produced in the series are not of the quality or performance level that the customer would want. But that does not stop the PLA, PLAAF, and PLAN from acquiring these weapons. The logic is that by the time the third or fourth batch of tanks, aircraft, or destroyers are made, the weapons system will have reached the desirable quality, and then the earlier versions will go back to the factory to be modernised to the requisite standard. The IAF, therefore, should initially be willing to take what HAL delivers with the expectation that these systems will be subsequently modernised to meet the required quality that the Air Force seeks.

Fourthly, one lesson of the Ukraine and Gaza wars, as well as Operation Sindoor, is that smart missiles matter. This goes against the ethos of air forces that are still obsessing over fighter jets that can engage in air-to-air combat. After all, we have all seen the movie Top Gun: Maverick. The fact of the matter is that in the new era of warfare, precision-guided missiles fired from beyond visual range are carrying out military missions effectively while not endangering pilots. What the IAF has to remember is that the Indian public gets upset hearing planes are downed, and when pilot Abhinandan was shot down after Balakot, it grounded all offensive operations to a halt as everyone got involved in the drama of a captured pilot. A missile strike on Nur Khan air base during Operation Sindoor may not be as sexy as a manned strike on the Iranian nuclear facilities, but it is an operational success.

With this in mind, make the AMCA. into a missile truck with a good radar and the ability to carry large and heavy missiles like the Brahmos. Mate the plane to AWACS so that they can initially direct the missiles without having the missiles turn on their active seekers and become visible to enemy aircraft.

All these steps, however, will require complete transparency from HAI, which, given its record, will be difficult, and for the IAF to understand that "Quantity has its own Quality." Two or three hundred AMCAs would give the IAF the capability to fight a two-front war, but to do so, the planes have to come off the factory floor in significant numbers. At the same time, one has to plan for the contingency that HAL may once again disappoint and that brings up the case for the Su-57.

Su-57

The IAF was initially a partner in the Su-57 project but walked out of it because the Russians were inflexible on design changes. There was also the belief in the IAF that it was not a true fifth-generation fighter, and the Russians were unwilling to give India the source code, which would have given the country the open architecture to further develop the aircraft's systems. It seems things have come full circle since the Russians are aggressively marketing the aircraft, and India has a shortage of combat squadrons.

The cornerstone of Russia's proposal lies in its offer of complete source code access (the software architecture), and Indian officials have noted that this level of technological latitude "eclipses anything previously granted by Western suppliers." Access to the software code would enable India to integrate domestically developed systems, like its Indian-manufactured mission computer and indigenous weapons platforms like the Astra MK-1 and MK-2 beyond-visual-range ge missiles, Rudram anti-radiation missiles, and precision-guided air-to-ground weapons.

Additionally, the Russians are offering the Okhotnik stealth drones, which can deliver ordnance and thus can serve as a complement to the manned air force. They are also configured so that the Su-57 pilot can direct them and use them as a force multiplier. Recognising that India has an immediate need for aircraft, the Russians are willing to supply up to 30 Su-57 by 2030 as an off-the-shelf buy and then begin license production in the early 2030s. Such a deal would provide the insurance of boosting squadron numbers and having a backup in case the AMCA is delayed, as most analysts expect it to be.

The question is whether the IAF will accept the aircraft given its past reservations, but this is likely to be a political buy that the Air Force will have to live with, and no one can argue that it will not help address the problem of declining squadron strength. The government may be pushed into buying the aircraft since India cannot buy from Turkey or the because there is a global shortage of such weapons.

The Missile Shortage

Not only is the production of fighters being delayed, but a similar problem exists with missiles. In 2024, the USA manufactured 550 Patriot missiles, and in 2025 is expected to rise to 650. That is an insufficient number to cover the needs of Israel, Ukraine, the United States, and its allies, Given that two Patriots have to be fired at an incoming missile, that would mean the stockpile would be exhausted fairly rapidly. In fact, in the three missile attacks by Iran on Israel, the US used a considerable amount of its stockpile of THAADS, Patriots, Aegis, and Sidewinder missiles to shoot down much cheaper Iranian ballistic missiles, cruise missiles, and drones. In the twelve-day war between Iran and Israel, the Iranians were able to degrade the Israeli Iron Dome and David's Sling anti-missile defences to about 65 per cent because the Israelis were unable to quickly replenish their missile arsenal.

From an Indian perspective, any future war would possibly mean India would face a similar problem with its stockpile of Brahmos, S-400, Scalp, Meteor, and Akaash missiles that would be exhausted fairly quickly. This is because the Pakistanis have learnt their lessons from Sindoor and will go to their suppliers-China and Turkey to get more drones and missiles to complicate the Indian air defence environment.

India, therefore, must invest in quickly building up its domestic production of missiles and in buying missiles from Russia, France, and Israel, although all three nations have their own military needs to fulfil. The French are seeking to build up their missile forces in light of the new drive towards NATO modernisation. The Russians are fighting their war in Ukraine and are using large numbers of missiles and drones to overwhelm Ukrainian air defences. This has required the Russian industrial base to ramp up production to meet the demand of its armed forces. As mentioned earlier, the Israeli missile stockpile has been depleted, and they too need to replenish it as soon as possible.

Yet all three nations want the profits that come from selling to India because the cost of the wars has hit their own economies. India should leverage this need by making it clear to the French and the Israelis that while it is happy to buy from them, it will have to be at normal market rates. After Doklam, the IAF ordered some precision-guided munitions from Israel, which readily agreed to dip into its war stocks to supply New Delhi. But given the urgency of the request, the Israelis sold the weapons at 150 per cent over market value.

Similarly, in the aftermath of Galwan, the IAF paid the French 150 per cent over market value for an urgent resupply of weapons. One is not arguing that the Israelis and the French were price gouging India, since this is the going rate for immediate transfers, but now both countries need sales so they can offer some leeway in pricing to India.

Drones

The last part of the modernisation effort includes the the induction of drones and missiles. The Indian private sector has successfully provided the armed forces with domestically manufactured assembled tactical drones that were able to inflict damage on Pakistani forward positions, but what is needed are Medium Altitude Long Endurance (MALE) drones like the Iranian Shaheds that the Russians are now building in large numbers and using over the skies of Ukraine.

The Russian Okhotnik is a more advanced drone, like the US-made Reapers, but both are relatively expensive machines. The Okhotniks are priced in the $5 million range, while the Reapers are in the $30 million range. Yet the Houthis were able to shoot down 22 Reapers, which was an embarrassment to the American armed forces, and India cannot afford such high-cost weapons, which are easy to bring down. In contrast, the Iranian Shaheds can carry ordnance and were able to attack Israel, which is a thousand kilometres from Iran. Further, the Israelis and Americans used far more expensive ordnance like the $500,000 AIM-9X Sidewinders to shoot down the Shaheds, which are valued between $20,000-$40,000 per unit.

Having lower-priced drones not only means they can be procured in large numbers, but bringing them down imposes a financial cost on the enemy and depletes its stockpile of anti-missile and drone defences.

While missiles are the face of modern warfare, it is important to remember that most of the guided missiles in the Indian arsenal are very expensive and have to be used sparingly. Missiles like the Brahmos, Meteor, and Scalp cost a lot of money and, of necessity, have to be used for high-value targets. Unlike Israel, which has a generous benefactor in the United States that provides it with an unlimited supply of missiles at subsidised rates, no country will provide India with such largesse. New Delhi, therefore, needs to build up a stockpile of its own indigenously produced weapons that are affordable and can be procured in large numbers.

Two such systems, which are cost-effective, are the Nirbhay cruise missile and the Pralay surface-to-surface missile. While not as advanced as Brahmos or Scalp, the great advantage of these systems is that they can complicate the defensive calculations of Pakistan. While Nirbhay is a cruise missile, Pralay is a surface-to-surface short-range missile which reaches its target at higher speeds, making an intercept more difficult than with the subsonic Nirbhay. That, in turn, will require using more advanced and costlier anti-missile systems. The Pakistanis will have to counter by firing weapons from their own arsenal, and that provides India with several advantages. Launching cheaper systems depletes the Pakistani arsenal, leaving it less capable when the more dangerous missiles start flying in. Further, the cost of anti-missiles will also be a major burden on the Pakistani exchequer, which will have to buy these systems in large numbers to counter the Indian threat.

The cost of defensive measures is important because wars are not just about inflicting physical pain on the enemy but also about extracting an economic cost from the opponent. As mentioned earlier, while China may sell weaponry at subsidised rates to Pakistan, it will not be sold for free, and this will exact a cost from the Pakistani exchequer.

Similarly, despite all the Islamic fraternity that Turkey's Erdogan might be displaying towards Pakistan, when it comes to arms sales be it fighters or drones or missiles-Ankara will expect to be fully paid for its arms exports to Islamabad. Pakistan may well bankrupt itself in entering into a high-technology arms race.

In procuring drones, there are two options here for the IAF: first, it should ask private industry to develop a system indigenously, and also find an external partner to work with to quickly bring a drone of that capability and price range into service. In this context, an international partner like Brazil or South Africa may be one for India to jointly develop drones with.

In conclusion, the IAF now faces a two-front air threat which will need to be countered with new aircraft and a surplus of missiles. Such a development of the force cannot be done overnight, given global supply constraints, so India has to act promptly and be willing to spend the needed resources to acquire the needed systems. Now is not the time to be penny-wise and pound-foolish, but to buy what the IAF needs.

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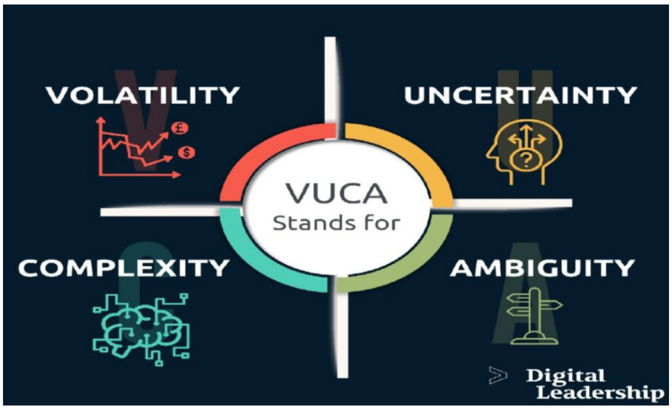
Air Power Musings: Navigating a VUCA World

Group Captain VP Naik VM | 07 October 2025

Source: CAPSS India | https://capssindia.org/air-power-musings-navigating-a-vuca-world/



Notional depiction of Russian A2/AD strategy in the European theater

On October 08, 2025, when the Indian Air Force (IAF) turns 93 years young, it stands at a defining juncture in its institutional evolution and development into a modern, future-ready, and strategic air force with power projection capabilities across continents. The past nine decades have seen the Indian Air Force (IAF) grow from a fledgling force to a force to reckon with, the fourth-largest air force in the world, and a professional outfit capable of taking on the myriad challenges that come its way in the 21st Century. From combat in the North West Frontier Province (NWFP) to the jungles of Burma (World War II), from pioneering feats of courage and valour to save Srinagar to landing at the highest airfield in the world and from targeting bunkers in Kargil to carrying out stand-off precision attacks from own side of the International Boundary (IB) during Op-Sindoor, air power has always been the first responder, IAF an instrument of choice and a force capable of delivering decisive firepower when and where it counts.

The contemporary security environment is significantly different from what IAF has seen over the past nine decades and is characterised by increased volatility, uncertainty, complexity and ambiguity (VUCA). The VUCA environment presents its own unique set of challenges and opportunities for IAF and air power. India's strategic environment is volatile, marked by uncertainty in the multi-polar world, complexity in modern warfare and ambiguity created by hybrid threats. While technology, information and doctrines matter, the ability to interpret, analyse, predict outcomes and take timely decisions largely depends on sound leadership; therefore, leadership will remain the decisive variable in this VUCA world. The paper aims to understand the intricacies of a VUCA world from an air power perspective and analyse leadership challenges that must be addressed for success in future wars.

Air Power in a VUCA World

Volatility classically refers to the speed and amount of change. Uncertainty denotes unpredictability of events and outcomes. Complexity implies a non-linear, interwoven geo-political landscape where events seemingly unrelated to one another create direct, indirect, or cascading effects on one another, and ambiguity highlights the decision dilemmas that are likely to arise due to prevailing uncertainty and opacity. As a technologically driven, decision-sensitive force, air power is largely affected by the interplay of the elements in a VUCA world. Technologies like Artificial Intelligence (AI) and Machine Learning (ML) have significantly changed the way air power is being applied. Unmanned systems, such as drones, quadcopters, and Unmanned Combat Aerial Vehicles (UCAVs), are altering the battlefield landscape, creating unique conditions not previously experienced. Hypersonic weapons and the use of space have exacerbated the quagmire and information has become weaponised to such an extent that narratives are deciding who the victor is and who is vanquished. In such an ambiguous and uncertain environment, it is not easy to arrive at decisions; therefore, there is a direct impact on the Observe, Orient, Decide and Act (OODA) loop, which is the cornerstone of air power application, posing unique challenges for leadership.

For India, the VUCA framework is a strategic reality, primarily due to a revisionist and uncertain China and an unpredictable Pakistan, which creates a significant amount of entropy. This high degree of disorder and randomness has been further compounded by America's newfound love for Pakistan and apparent animosity with India. The Russia-Ukraine war and the Israel-Hamas conflicts have shown the world that in today's multipolar, intensely divided world, no one is willing to take a step back, resulting in highly destructive and long-drawn conflicts. On the other hand, Op-Sindoor has shown that conflicts could also be very short and intense, especially if one's military and political objectives are clearly outlined. The conflict termination criteria are well articulated. The bottom line is that there is perpetual disruption. Amidst that disruption, air power must learn to retain its centrality and provide speed, precision and flexibility to mitigate volatility and uncertainty.

Yom Kippur Moments

On October 6, 1973, the Arab alliance of Egyptian and Syrian forces launched a surprise attack on Israel on Yom Kippur, the Jewish holy day of atonement. The attack resulted in heavy casualties and equipment loss in both the Sinai Peninsula and the Golan Heights. The surprise factor was very high as the Israelis did not expect anything to happen, especially on a holy day like Yom Kippur. On October 7, 2023, Hamas launched a coordinated attack on Israel on Shemini Atzeret, a Jewish holiday. Many Israeli Defence Forces (IDF) soldiers were on leave, and Israel was focused primarily on its Northern borders rather than the Gaza Strip. The assault began at around 0630 AM with a barrage of over 2200 rockets launched into Israel in just 20 minutes. The barrage of rockets reportedly overwhelmed the Iron Dome system. As this was happening, at least 1,500 militants of Hamas infiltrated Israel at dozens of points using the land, sea and air mediums (para gliders). They caused a large number of Israeli casualties. About 1,200 people were killed in the assault, which included many civilians. If one were to analyse the two attacks, a conclusion that can be drawn is that both attacks took place on a holiday, surprise was a key element, and it was a failure of intelligence. Most importantly, the Israelis were not prepared for it.

The VUCA world is similar. Amidst all the volatility, uncertainty, complexity and ambiguity, are we as a nation adequately prepared for a 'Yom Kippur Moment'? Kargil, Pahalgam, Galwan, and Pulwama are some of India's intelligence failures that have led to India's Yom Kippur moments. Are we prepared for a multi-domain attack simultaneously targeting not only our military installations but also our critical civilian infrastructure? Are we ready for an unconventional attack using weapons and equipment that we have not thought of, like the use of paragliders by Hamas? Is our intelligence apparatus examining the right markers for such an event to unfold? When analysing intelligence data, are we correlating inputs in different domains, or are we still looking in silos? Do we have the wherewithal to response to surprise attacks on multiple fronts and in multiple domains? If the answer to any of these questions is no, then it is time to start introspecting. As a nation, we need to be prepared for our 'Yom Kippur Moment' without waiting for it to happen and then reacting.

Managing the VUCA World: Paradigm Shifts

Doctrinally, volatility requires a paradigm shift from conventional planning to adaptive and associative planning. Technology must be leveraged to simulate unpredictable scenarios and uncontrolled escalation, testing the agility of our Command and Control (C2) structures and readiness postures. Gone are the days of lethargic large-scale mobilisation of the armed forces and 30-day war packs. Volatility does not only mean disruption and interruption, but it is also a counter-strategy and must therefore become a part of our planning assumptions.

In a volatile world, uncertainty is inevitable; therefore, the way events unfold cannot be second-guessed when they start unfolding. To stay one step ahead, we must harness technology such as Generative AI and big data analysis to explore nuanced possibilities that can then be war-gamed. While using the full potential of Generative AI is still some years away, we must make a start now. Deterrence will suffer when events and outcomes are unpredictable. Yom Kippur Moments can be avoided by harnessing technology to bring credibility and intent to our deterrence capability.

Modern warfare is inherently complex, primarily due to its multi-domain nature. The land, sea, and air domains have now become interlinked with cyber and space domains; information has become a weapon and operations in one domain inevitably affect operations in other domains. We must learn to manage complexity through doctrines, realistic training, education, and integration of systems to create a system of systems that can undertake multi-domain operations.

Ambiguity affects information and perception, and it cannot be removed from modern conflict. Decision dilemmas arising from ambiguity will increasingly determine the outcome of a war. The side that has the fewest decision dilemmas will have the upper hand. A shorter OODA loop may not be the only solution, because in modern conflict, multiple OODA loops will interact with each other. There will be an overload of information, and the ability to sift through volumes of data to arrive at meaningful deductions will eventually become more important than a shorter OODA loop.

The bottom line is that there is a need to re-evaluate our doctrines, operating procedures, response mechanisms, intelligence apparatus and capability development plans, which would cater to warfighting in a VUCA world.

Leadership Challenges

Military leadership, primarily characterised by hierarchy, close control, and strict, enforceable discipline, faces an existential threat when confronted with a VUCA world. Attributes like tradition, centralised control and strict adherence to precedent can impede agility in an environment where change is constant. The essence of leadership in the future will lie in the ability to sense, decide and act faster than changes in the operational environment.

Outdated Standard Operating Procedures (SOPs), tactics and techniques will become serious hurdles. For example, switching off the Radar Warning Receiver (RWR) during rejoin and within airfield control zones due to inadvertent activation of the Counter Measures Dispensing System (CMDS) may prove dangerous during a 'No War, no Peace (NWNP)' scenario, as the enemy may have weapons which can target their own aircraft at launch and during recovery for landing. It is essential to remember that India is constantly in an NWNP scenario. Similarly, just because a particular tactical action worked in an earlier situation does not mean it will work in the future as well. Smart enemies will not do what you expect them to., In a VUCA environment, the most essential task confronting leaders is to figure out what the enemy is likely to do and accordingly update SOPs, tactics, and techniques.

Technological volatility must be addressed by technologically fluent leadership. Leaders who cannot fully comprehend the capabilities of systems placed under their command risk irrelevance. Professional competence, continuous education and cross-domain exposure are essential for effective C2 in modern warfare.

Uncertainty, unlike volatility, stems from the unpredictability of events and outcomes and therefore poses a direct challenge to a leader's confidence in available information and the reliability of established assumptions. Making sound decisions amid imperfect knowledge will hence become essential. The more variables there are, the greater the uncertainty, and given the nature of air operations, this will only increase with increased fog of war. Leaders must therefore learn to interpret evolving patterns rather than expect the normal to take place. Pre-set plans may not work in uncertain situations, and flexibility, adaptability, and the ability to think beyond one's own domain will go a long way. This would require institutional changes, such as training in a VUCA environment, introducing uncertainty into routine activities, and creating entropy in seemingly mundane tasks. Disruptive training, which fosters cognitive flexibility and encourages out-of-the-box solutions, will help develop future leaders. Disruptive training is not training at odd hours; that is just a tiny part of it. Disruptive training is training by disrupting routine patterns and the usual way of doing things. For example, in combat scenarios, there may be a situation that allows landing only in tail winds. How many times do our trainees practice this? Answers to questions beginning with 'What if?' are essential to deal with combat planning and execution in a VUCA world. A leader must be able to picture multiple 'What ifs?' to create effective and doable plans. They must also be war-gamed to arrive at tangible and implementable courses of action. Adversaries of the future will try to outthink their opponents at every stage, making it a significant leadership challenge.

When faced with complexity, effective leadership must view modern military operations as interconnected occurrences rather than isolated missions. For example, when Blue Land launches its Offensive Counter Air (OCA) missions, the entire Red Land would undertake Air Defence (AD) missions, and the pattern would reverse when Red Land launches its OCA forces. In reality, OCA and AD will co-occur in multiple domains and spread across the entire front. There is a need to revamp our training regimen to align with operations in a VUCA world. Leaders of tomorrow must change their mindset and reimagine training paradigms to make them more realistic and contemporary. Operations in an environment of denial are far more complicated than those undertaken when all systems are functioning properly. To be able to do that, leaders of tomorrow should have been trained in such environments. Capability development plans must address the challenges inherent to operating in such environments. For example, what if GPS is made unavailable in the next war? How are we going to undertake stand-off precision attacks? Do we have an alternative system? Are our aircraft and weapon systems equipped with alternative technology? Most Western surface-to-air weapon systems rely on a GPS fix to initialise. What happens if that GPS fix is not available? Another major issue facing us is the so-called peace-time attitude. Most personnel in service may not see combat throughout their careers. But, when it actually happens, our peace-time training needs to take over and aid in dealing with the arising uncertainties and complexities. While we would be expected to adopt war-time procedures, peacetime procedures would largely prevail because they would have become a habit and second nature. Our training during peace -time needs to be "train in peace as you fight in war,' or as close to war fighting as possible and feasible, only then will they become second nature. By having two separate sets of procedures, we are adding to the already existing complexity of the situation. Examples of this situation include the carriage of personal arms during peace-time training missions, the use of Identification Friend or Foe (IFF) during take-off and rejoin, night operations with minimal lighting, no radio telephony (R/T) missions, and simultaneous activation of ground defence and air defence measures at a base. These are some institutional challenges that future leaders must address as soon as possible.

Ambiguity cannot be eliminated, but can definitely be out-thought and out-led. Multi-domain warfare, hybrid warfare, and information warfare are three types of warfare adding to the ambiguity quotient. In ambiguous environments, leaders are likely to face ethical dilemmas, decision paralysis, shifting rules of engagement and large-scale information distortion. The first casualty of ambiguity is effective communication. If a leader is unable to communicate effectively with their subordinates, orders may be misinterpreted, leading to total disarray. Training in an environment of denial, redundancy in communication and clarity of thought are a few tools modern leaders must develop to remain relevant in ambiguous situations.

Conclusion

As IAF approaches its centenary in 2032, leadership will determine whether it remains a reactive force or evolves into a proactive aerospace power. IAF@100 will demand leaders who can effectively navigate a VUCA world. Leadership is an institutional competency and not just a personal trait. The IAF must nurture younger generations in a VUCA environment, because sound and effective leadership will remain the IAF's greatest weapon system, far more enduring than aircraft and way more resilient than technology. Leadership in a VUCA world is not about predicting the future, but rather about preparing for it. We must institutionalise adaptability through doctrine, training, education and culture. The future demands leaders who can handle volatility with alacrity, uncertainty with flexibility, complexity with equanimity and ambiguity with dexterity.

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Too Long, Too Powerful: Why India Did Not Consider Japan's Advanced IHI XF9-1 Engine for AMCA Mk2 Fighter

Jaydeep Gupta | 21 October 2025

Source: Defence.in | https://defence.in/threads/too-long-too-powerful-why-india-did-not-consider-japans-advanced-ihi-xf9-1-engine-for-amca-mk2-fighter.15852/

The development of a fifth-generation fighter jet is one of the most complex challenges in modern defence, and selecting the right engine is critical to success.

India's ambitious Advanced Medium Combat Aircraft (AMCA) program, which aims to deliver a domestically built stealth fighter to the Indian Air Force by the mid-2030s, recently concluded a high-stakes search for its advanced Mk2 variant engine.

Among the top contenders was a technologically advanced proposal from Japan. In mid-2025, Tokyo offered its cutting-edge IHI XF9-1 turbofan engine, not just for purchase, but for co-development and local production in India.

Despite the offer's alignment with India's

'Aatmanirbhar Bharat' goals, it was ultimately set aside. A deeper look reveals that the Japanese engine, while impressive, was a poor fit for the AMCA due to critical technical, dimensional, and strategic factors.

An Impressive but ILL-Fitting Offer

The Japanese proposal was first formally discussed during a Defence Ministers' meeting in Delhi in May 2025.

Japan's Acquisition, Technology & Logistics Agency (ATLA) and IHI Corporation presented the XF9-1 as the ideal solution for the AMCA Mk2, which requires a powerful engine in the 110-130 kilonewton (kN) class.

The offer was comprehensive, including full technology transfer (ToT), shared intellectual property rights (IPR), and an invitation for India's Gas Turbine Research Establishment (GTRE) to review the technology in Japan.

On paper, the XF9-1 engine's specifications are remarkable.

Designed as a "high-power slim engine," it delivers over 107 kN of dry thrust (without afterburner) and a massive 147 kN with its afterburner. This is significantly more powerful than the 98 kN thrust of the General Electric F414 engine that will power the initial AMCA Mk1.

Furthermore, the Japanese engine is packed with next-generation features. It uses advanced materials like ceramic matrix composites to withstand extremely high turbine temperatures around 1,800°C.

It also generates 180 kW of electrical power, a feature designed to support future systems like Al-driven avionics and laser weapons. Its three-dimensional thrust-vectoring nozzle also promised superior agility, putting its technology on par with engines used in top-tier fighters like the F-35.

The Deal-Breaker: A Problem of Size

Despite these advantages, engineers at India's Aeronautical Development Agency (ADA) faced a fundamental integration problem.

The AMCA's airframe was designed around the compact dimensions of the GE F414 engine, which measures approximately 3.9 metres (154 inches) in length and 0.89 metres (35 inches) in diameter.

While the XF9-1's 1-metre diameter was considered manageable, its length proved to be the deal-breaker. At 4.8 metres long, the Japanese engine is nearly a full metre longer than the F414.

Fitting the XF9-1 would have required a complete and costly redesign of the AMCA's rear fuselage and engine bay.

This major structural change would have delayed the program by years, increased its overall cost, and likely compromised the aircraft's carefully designed stealth profile, weight distribution, and internal fuel capacity.

The AMCA has an aggressive timeline, with prototype flights planned for 2029 and induction by 2035. The XF9-1 was simply not a "drop-in" replacement.

A Case of "Overkill" and Strategic Risk

Beyond the physical mismatch, the XF9-1 was also deemed too powerful for India's needs. Its 147 kN thrust far exceeded the AMCA Mk2's 120 kN requirement.

While this may seem like an advantage, such excessive power, or "overkill," can be inefficient for a medium-weight fighter, putting unnecessary strain on the airframe without providing a proportional benefit.

Broader strategic factors also played a role. Japan has since become a core partner in the Global Combat Air Programme (GCAP), a multinational project with the UK and Italy to build a sixth-generation fighter.

With Japan's resources and focus shifting to developing a new engine with partners like Rolls-Royce, Indian officials had valid concerns about Tokyo's long-term commitment to the separate XF9-1 project.

India could not risk a repeat of its own Kaveri engine program, which suffered from decades of delays.

The "Perfect Fit" Solution from France

In July 2025, India announced it had selected France's Safran as its partner. The French proposal, valued at around $7 billion, involves co-developing a new 120 kN engine perfectly tailored to the AMCA's needs.

Crucially, the Safran engine is being designed to "seamlessly fit" within the existing F414-based engine bay, requiring only minor modifications. This decision saves invaluable time and resources for the ₹61,000 crore AMCA program.

The deal includes a 100% transfer of critical technologies, including the complex single-crystal turbine blades, and grants India full intellectual property rights.

The timeline aligns perfectly with India's goals, targeting the first engine test flight by 2028 and full-scale production by 2035.

This new engine is also expected to be scalable, allowing it to power the Indian Navy's future Twin-Engine Deck-Based Fighter (TEDBF), securing India's combat aviation future for decades to come.

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AIR POWER

EU Sets 2027 Target for Anti-Drone System to Defend Against Russia

Jaroslav Lukiv | 16 October 2025

Source: BBC | https://www.bbc.com/news/articles/c4gz2ppye5zo

Several EU states have already backed plans for multi-layered drone defences

EU foreign policy chief Kaja Kallas has said a new anti-drone system should be "fully operational by the end of 2027", as part of a drive to toughen defences against Russia and be fully prepared for possible conflict by 2030.

"Drones are already redefining warfare. Having drone defences is no longer optional for anyone," Kallas said, referring to Russia's ongoing war in Ukraine and fears that Moscow may attack the EU.

The European Commission's "defence roadmap" also proposes strengthening the EU's eastern borders and building air and space "shields".

Several EU nations have faced Russian incursions into their airspace and US President Donald Trump has urged the bloc to do more to defend itself.

The European defence plan comes amid growing European fears that Russia will continue its westward aggression after the war in Ukraine is over, as well as continued ambiguity over Trump's long-term commitment to European security.

"Danger will not disappear even when the war in Ukraine ends. It is clear we need to toughen our defences against Russia," Kallas told reporters in Brussels on Thursday.

Although there seems little chance of the war ending soon, Trump says he is now having a "lengthy" conversation with Russian President Vladimir Putin on the phone, ahead of talks with Ukrainian President Volodymyr Zelensky on Friday.

Trump has indicated that if Putin does not not move to end the war, the US could send Ukraine long-range Tomahawk missiles - a potential move already described as "escalation" by the Kremlin.

Standing alongside Kallas, European Defence Commissioner Andrius Kubilius stressed that "our roadmap shows all the major milestones to achieve defence readiness by 2030, so we can deter Russian aggression, prevent war and preserve peace".

Putin has repeatedly denied that Moscow has any aggressive plans towards the EU. In June, he said the "myth that Russia is planning to attack Europe, NATO countries is an unbelievable lie... nonsense".

The EU's executive Commission said the 27-member union should be ready by 2030 to "respond to any crisis, including high-intensity conflict".

It also urged the bloc to "close critical capability gaps" - including in air and missile defence, and artillery systems - "through joint development and procurement".

Many EU countries are also members of NATO and its chief, Mark Rutte, said they were working together to protect member states on the eastern flank from aerial threat.

The EU stressed its "flagship" projects would be developed in "close co-ordination" with NATO, and would not duplicate the Western defensive alliance's work.

No estimates were given to the overall cost, but Kubilius said "we're not talking here about hundreds of billions".

The "defence roadmap" still needs to be approved by member states at a leaders' summit next week.

However, a number of EU states have already backed plans for a multi-layered "drone wall" to quickly detect, then track and destroy Russian drones.

In recent weeks, tensions have escalated between the EU and Russia, after Poland and Romania - both NATO members - said Russian drones had breached their airspace.

And Estonia - another NATO member - in September requested urgent consultations with other alliance members after saying that Russian warplanes had violated its airspace and stayed there for 12 minutes.

Russia, which launched its full-scale invasion of Ukraine in February 2022, said its planes were on a "scheduled flight... in strict compliance with international airspace regulations and did not violate the borders of other states".

A number of European politicians and military experts have said that Russia's aim is to test NATO's capabilities and and try to sow discord within the alliance.

Several NATO members reacted to the reported Russian incursions by sending troops, artillery, and air defence systems to secure the alliance's eastern flank.

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Air Superiority in the Twenty-First Century: Lessons from Iran and Ukraine

Alexander Palmer and Kendall Ward | 10 October 2025

Source: CSIS | https://www.csis.org/analysis/air-superiority-twenty-first-century-lessons-iran-and-ukraine

JACK GUEZ/AFP/Getty Images

Introduction

Before Russia invaded Ukraine, its Aerospace Forces (VKS) and missile forces were considered likely to play a major role in forcing Ukraine's rapid collapse. But as Russia's offensive unraveled in early 2022, commentators declared Russia's air force to be "missing" and its performance to be "perplexing." In contrast, the Israeli Defense Forces (IDF) achieved air superiority over Iran in less than four days, an achievement made more impressive by the fact that Tehran is nearly 1,000 miles from Israel's nearest airbase.

To better understand air war in the twenty-first century, this analysis compares Israeli, Russian, Iranian, and Ukrainian performance across several dimensions. Few of the lessons are novel; Israel's success and Russia's failure reinforce old lessons about pursuing qualitative superiority in technology and training, operational flexibility, accurate and timely intelligence, and effective use of combined arms. The most important new development is the increasing ability to strike ground-based air defense (GBAD) systems from threats within their lethal envelopes, the three-dimensional space in which air defenses can kill incoming threats, along with the corresponding need to defend against such attacks. Israel's use of Mossad special operations forces to conduct unmanned aerial system (UAS) and missile strikes against Iranian air defense systems from within Iran demonstrate the risk that small precision-strike assets can pose to a country's air defenses. Unconventional attacks—such as those conducted by Mossad against Iran and by Ukraine against Russia in Operation Spider's Web—are repeatable because these or other states could conduct similar attacks in the future. Although this type of attack involves significant preparation and cannot be repeated without rebuilding the networks that enabled them, they represent an ongoing threat to air defenses and strategic assets that air defenders must respect.

Due to the differences between the Russian and Israeli air campaigns, this analysis compares Operation Rising Lion with only a narrow slice of the Russian campaign. At the beginning of its 2022 invasion, Russia prioritized attacks against Ukrainian air defenses, and its plan to rapidly seize Kyiv and decapitate the Ukrainian government required airborne insertion of forces near the capital—and therefore required suppression or destruction of Ukraine's air defenses. This analysis therefore directly compares the 12-

day Israeli campaign, throughout which the Israeli Air Force (IAF) was able to operate freely over Iran, with the first two weeks of the Russian operation. During this period, Russia sought and, in several locations, achieved air superiority. But by the ninth day of Russian operations, Ukraine had partially reconstituted its air defense network and Russian control of the skies was lost, although Ukraine took several more weeks to fully deny the VKS the ability to operate over its territory.

Success and Failure in the Skies

Israel's strikes against Iran and Russia's invasion of Ukraine differed in their goals, assumptions, and requirements. Operation Rising Lion incorporated special forces, cyber, and informational elements, but air and missile forces were always going to provide the decisive capabilities—the operation depended on seizing and maintaining air superiority long enough to degrade Iran's nuclear infrastructure. In contrast, Russia's 2022 invasion of Ukraine was primarily a ground operation. The Russian military did not assume that success depended on air superiority in the way the Israeli operation clearly did.

Nevertheless, the Russian and Israeli campaigns began in much the same way, with air and missile strikes against their adversaries' militaries—especially their air defense infrastructure. Israel's initial strikes, including the well-publicized Mossad operations of June 13, 2025, killed the leadership of Iran's strategic air defense and long-range strike unit, the Iranian Republican Guard Corps (IRGC) Aerospace Forces. Over the next 24 hours, the IAF struck 100 targets with nearly 200 sorties of manned and unmanned aircraft, decimating Iran's integrated air defense system. Russia also began its 2022 invasion with a strike campaign intended to degrade and destroy Ukrainian air defenses. During the first week of the conflict, Russia launched more than 200 short-ranged ballistic missiles into Ukraine. Russian combat aircraft also flew roughly 140 sorties per day, attacking more than 100 air defense targets in the first 72 hours of the invasion.

Israel's success was comprehensive—the IDF announced that it had air superiority on the fourth day of the conflict—and while Russia's was not, the VKS did achieve air superiority in key locations. In the first three days of the conflict, Russia managed to both insert a 34-helicopter air assault into Hostomel airport and conduct sorties up to 300 kilometers into Ukraine. However, Russia did not expand or maintain its air superiority. Slow-moving Ukrainian Bayraktar TB2 UAS struck Russian ground forces when they should have been easily destroyed by Russian air or air defense forces. Russia was unable to defeat Ukraine's air forces, which fought the VKS until about March 3, 2022, when Ukraine's GBADs had recovered from Russia's suppression. From that point onward, the VKS grew increasingly ineffective, and by early April 2022 it had effectively ceased attempts to penetrate Ukrainian airspace. In the end, Israel did not lose a single manned aircraft or pilot—one F-16I navigator claims that Iran did not fire a single surface-to-air missile—while independent researchers confirmed the destruction of multiple Russian manned-combat aircraft in the opening weeks of the campaign.

History, Doctrine, and Organization

Israel has a long history of offensive air operations, but Russia does not. Due to Israel's limited strategic depth and its proximity to hostile nations and actors, IDF doctrine emphasizes the rapid achievement of air superiority to enable preemption, rapid escalation, and freedom of action. The IAF does not merely support operations; Israeli officials see it as a critical enabler of Israel's national defense, designed to rapidly seize control of the air in support of ground forces and to impose strategic costs on adversaries. For more than 50 years, Israel has prioritized technological, operational, and doctrinal improvements to increase the IAF's ability defeat adversary air defenses. Unlike many of its adversaries, the IAF emphasizes suppression and destruction of enemy air defenses as operational imperatives in air force doctrine, training, equipping, and operational employment.

In contrast, Russia has no significant history of offensive air superiority operations. Russian air forces have been employed either in air defense or close air support missions for most of the country's history, and they have never been pitched against a sophisticated enemy air defense system like that of Ukraine. Despite the combat experience its pilots gained in Syria, that campaign did not involve disrupting or defeating an adversary's air defense network. Rather than attempting a U.S.- or IAF-style air superiority campaign in Ukraine, Russia appears to have sought only limited air superiority over corridors vital to its plan to quickly seize Kyiv and topple the Zelenskyy government. This may be because, unlike Israel and the United States, Russia does not see air superiority as necessary to enable ground maneuver. Its ground forces rely much more on artillery than on airpower.

As a result, struggling Russian ground commanders were not prevented from redirecting assets from the air superiority mission before Ukraine's GBADs had been destroyed and air superiority seized. This was a critical limitation of the air superiority campaign; even in the absence of Russia's many other failings, the ground forces' redirection of air superiority assets alone would have made it difficult for the VKS to consolidate or expand its gains. Russia's subordination of the VKS to the ground forces has even drawn criticism within Russia, despite restrictions on negative speech about the war.

Israel's emphasis on air superiority and Russia's corresponding de-emphasis led to different patterns of investments in materiel and training over the previous decades. For instance, the IAF's deliberate training against S-300s—the most effective air defense platform of the Iranian armed forces—began as early as 2007. Furthermore, the IAF acquired and fielded the expensive F-35I platform despite significant domestic opposition, a key investment in air capabilities. In contrast, VKS training focuses on narrow tactical situations using small homogenous groups of aircraft rather than integrated strike campaigns, which limits its applicability to an air superiority campaign. Russia has also underinvested in important air superiority equipment such as targeting pods and precision munitions, which are important for the dynamic targeting of mobile GBADs.

The Conventional Balance

Going into the conflict, Israel had overwhelming qualitative superiority over Iran. The IAF is one of the world's most capable air forces. The F-35 is one of the world's most advanced warplanes, with remarkable stealth and computing power that enables more effective use of Israel's less-advanced aircraft. Israel also modifies its imported F-15I, F-16I, and F-35I aircraft with advanced electronic warfare (EW) capabilities, avionics, communications systems, weapons pods, and enlarged fuel tanks to increase interoperability, range, and lethality in contested airspace. In contrast, Iran's air defenses were made up of a mix of Iranian, Soviet, and Russian systems that—where not obsolete—were poorly integrated. While its air forces did not enter the fight, Iran's combat air fleet is ancient, consisting of U.S. aircraft produced before the 1979 Islamic Revolution. There is little reason to believe that Iranian air forces would have posed much of a challenge to the IAF.

Ukraine blunted the Russian campaign through aggression, pilot skill, and an apparent willingness to accept greater losses than Russia.

Russia's qualitative superiority was much more uneven. It had enormous technological superiority over Ukraine's air force, but Ukrainian pilots proved at least the equals of their VKS counterparts. Ukrainian pilots have reported that Russian aircraft "completely outclass" their Ukrainian counterparts from a technical standpoint, particularly in radar and air-to-air missile performance. But Ukraine blunted the Russian campaign through aggression, pilot skill, and an apparent willingness to accept greater losses than Russia. In addition, Russia's most advanced combat aircraft—the Su-57 fifth-generation multi-role fighter—was conspicuously absent from the air war over Ukraine.

Although the VKS was technologically superior to the Ukrainian air force, it did not exhibit the same level of superiority over Ukrainian GBADs. Russia's ISR aircraft already struggled to locate enemy radars during the 2008 Georgia war, and its development of advanced ISR assets since has lagged. Its most modern ISR aircraft, the Tu-214R, was not fielded in Ukraine in significant numbers and may have fallen so short of VKS expectations that its production was cancelled. The VKS seems to rely primarily on antiradiation missiles (ARMs) for suppression and destruction of Ukrainian GBADs, but Ukrainian GBAD operators have been able to counter ARMs by "blinking" their radars off and on. The Ukrainian GBAD network was also much more advanced than that of Iran, meaning that the VKS had much less of a technological advantage over Ukraine than Israel did over Iran. After Russia's invasion of Crimea and the Donbas in 2014 and 2015, Ukraine invested significantly in its GBAD network. It modernized much of its S-300 inventory, developed modern replacements for

Soviet-era surveillance and target-acquisition radars, and upgraded the hardware and software of its GBAD systems, adding components such as the Ukrainian-made 35D6M wide-area surveillance and targeting radar.

Questions of quantitative superiority are impossible to resolve because there is a lack of data on Iran's air defense network. Israel operates around 240 combat aircraft, while Russia employed about 350 in its 2022 invasion of Ukraine. On the defenders' side, Ukraine operated about 250 M-300PS/PT systems, 72 9K37M Buk M1 systems, and about 100 short-range systems, most of which were 9K33 Osa systems. Meanwhile, Iran operated at least 10 S-200 and 32 S-300 long-range systems, about 50 medium-range Mersad systems, and at least 250 FM-80 and 29 9K331 Tor short-range air defense systems. However, Iran also operated an unknown number of medium-range 3rd Khordad, 15th Khordad, and Talash systems and a variety of point-defense systems, making it impossible to compare the numerical balance between Russia and Ukraine with the balance between Israel and Iran.

Special Operations

Special operations were critical to both Israeli and Russian planning, but Israel dedicated its special operations to the air superiority effort while Russia targeted Ukraine's command and control systems. Crucially, Israel's special operations forces targeted Iranian GBADs in a way Iran did not expect and against which its GBADs had no defense: from within Iran itself.

Israeli special operations consisted of at least two key lines of effort. The first was the infiltration of precision weapons systems—missiles and drones have been publicly revealed to have been used—into hidden bases within Iran, which were then used to strike key Iranian air defense and missile systems from short range. The second consisted of an effort to kill Iranian military leaders in the early moments of the campaign.

While a long- or medium-range air defense system can target an aircraft seeking to engage it, it is helpless against a swarm of drones launched from close range.

These efforts were central to Israel's achievement of air superiority. The IDF chief of staff stated that the IDF's air superiority campaign was "made possible, among other things, thanks to full coordination and deception by air and ground commando forces" operating deep within Iran. The UAS attacks almost certainly targeted air defense systems from within the defenses' lethal envelopes: While a long- or medium-range air defense system can target an aircraft seeking to engage it, it is helpless against a swarm of drones launched from close range. Meanwhile, the killing of Iran's IRGC commanders likely paralyzed strategic decisionmaking within its centralized air defense command, because the people who were supposed to make those decisions had been killed.

In contrast, Russian special operations efforts did not specifically target Ukrainian air defenses. Instead Russia's special operations campaign was intended to achieve the surrender of Ukraine's armed forces and the collapse of the Zelenskyy government. As a result, the campaign primarily consisted of a series of information operations conducted against Ukraine's military leadership, frontline commanders, and communities, along with cyberattacks against Ukrainian state communications and assassination attempts against Ukrainian leadership. Specifically, Russia sought to isolate frontline units from Kyiv using cyberattacks and undermine cohesion through personalized appeals to specific commanders. There is no reason to believe that Russia conceived of its information operations as pertinent to the air superiority effort. One comprehensive analysis concluded that such an effort would likely have been futile given Russia's theory of victory: " T he one part of the Russian invasion plan where obstruction, isolation and negotiated capitulation could not be achieved in theory was the Ukraine air defence system."

Israel's special operations did not aim for "obstruction, isolation and negotiated capitulation." Its efforts were destructive first and psychological second. Although successful assassinations of Ukraine's political leaders might have triggered the collapse of the Ukrainian armed forces, predicting the psychological effects of new information on an adversary is extremely difficult. In contrast, killing an entire layer of a military hierarchy and removing critical nodes of its defenses can more reliably be assumed to have a significant effect on the organization's ability to operate. Russia would have benefited from comparable efforts enabling deliberate intelligence, operational preparation, and advanced force operations within Ukraine to focus on destructive effects to achieve air superiority.

Battlefield Intelligence

Both Israel and Russia had extensive targeting information at the beginning of their campaigns, but only Israel effectively exploited it. In November 2024, Israeli intelligence and air force officials worked in tandem to develop a comprehensive list of military targets, including equipment and persons, in order to decapitate, paralyze, and destroy Iranian air defenses. Over the ensuing months, Israeli intelligence maintained effective surveillance of their intended targets through human and technical intelligence collection, providing actionable intelligence for rapid decisionmaking and dynamic targeting. According to one former Mossad official, the majority of information collection for Israel's initial operation was done through cyber- and signals-based intelligence, with its long-range precision strikes enabled by cutting-edge Israeli technology and almost certainly with U.S. intelligence support.

Russia had also been developing human source networks inside Ukraine for years. These networks were expected to play a major role in the aforementioned information operations, but Russia's human sources also provided extensive targeting information prior to and during the invasion. Most of Russia's long-range missile strikes targeted air defense sites that had been identified in the months leading up to the invasion, and Russia focused on quickly destroying fixed radar, surface-to-air missile, and command sites in the opening phase of the conflict. Russia managed to strike more than 75 percent of Ukrainian air defense sites in the first few days of the invasion, although the destructive effects were limited. Russia does not appear to have sufficiently updated its target lists before the strikes began: Many of its missiles struck locations from which Ukrainian mobile GBADs, ammunition stockpiles, and aircraft had already been moved. Sometimes the movement immediately preceded the strike and was triggered by U.S. warnings, but in other cases, the assets had been moved years before, demonstrating that Russia failed to maintain timely target lists.

Had Russia developed a comprehensive multi-intelligence approach to its targeting, it would have been more likely to successfully exploit its numerical superiority in aircraft and long-range missiles to destroy Ukraine's mobile air defense systems.

Russia's information problem persisted beyond the opening salvos. Targeting plans were created every 24 hours—much too slow to destroy Ukraine's mobile systems following successful suppression. In addition, targets appear to have been prioritized based on the order in which information was received, and old locations of the same target were sometimes not removed, further undermining the reactivity and efficiency of Russian forces. Adding to the intelligence issues, battle damage assessment, the process by which militaries determine the level of damage done by a particular attack, was ineffective. Without rapid and accurate battle damage assessment, follow-up strikes to finish a suppressed or damaged but undestroyed target cannot be ordered in time. Rather, the Russian military appeared to assume that every strike was effective, allowing suppressed GBADs to survive. Had Russia developed a comprehensive multi-intelligence approach to its targeting, it would have been more likely to successfully exploit its numerical superiority in aircraft and long-range missiles to destroy Ukraine's mobile air defense systems.

Russia was further hampered by underinvestment in airborne command and control or intelligence, surveillance, and reconnaissance (ISR) assets. Russian military commentators have identified that shortages in airborne early warning and control system (AEW&C) aircraft, ISR, drones, signals intelligence, and integrated command and control likely contributed to the VKS' struggle to establish air superiority in Ukraine. The VKS operates 15 AEW&C of the A-50 family, with perhaps half (or even fewer) in working condition. Given the age of the fleet, these platforms fall significantly short of the capabilities offered by their Western counterparts.

In contrast, Israel clearly places a much greater emphasis on these platforms than does Russia. The IDF possesses four AEW&C aircraft, all of which were developed in the twenty-first century and are in working order, giving the IDF roughly twice as many AEW&C aircraft per combat aircraft as the VKS. Israeli AEW&C aircraft are also almost certainly of higher quality than Russia's, given the latter's acknowledged neglect of its AEW&C systems. In addition, Israeli F-35Is operated in an ISR role as part of an integrated strike package in Operation Rising Lion, and the lack of Russian Su-57s in Ukraine deprived the VKS of anything approaching that capability. Although Iran represented a much easier target than Ukraine, even Russian Defence Minister Andrey Belousov acknowledged Russia's need to deliver more EW and ISR systems to the battlefield in 2024.

Force Employment

Force employment is how a military behaves in combat—especially the way in which a force coordinates fire and movement across different units and weapons—and is frequently used to explain battlefield success. Accordingly, the specific techniques, tactics, and procedures employed in an offensive air (or air denial) campaign by military forces and their enablers can significantly influence their ability to achieve operational objectives, often regardless of technological or numerical advantages. In this regard, force employment helps explain Israel's success and Russia's failure across three main tactical behaviors: (1) the attacker's employment of heterogenous strike packages, (2) effective integration of multidomain effects, and (3) the defender's employment of GBADs in dispersed mobile units. Israel's ability to employ its forces more effectively than Russia was likely further increased by the higher level of training received by Israeli pilots.

Coordinating multiple types of weapons allowed Israel to mass effects rapidly from ground-based long-range missiles and aerial attack platforms. Israeli strike packages seem to have at least sometimes employed one F-35I in an ISR role flying ahead of one or more F-15I or F-16Is. The IAF also employed a mix of precision-guided glide bombs and air-launched missiles, including ballistic missiles. Specific weapon-to-target pairing for the IAF during the campaign is somewhat speculative, but varying loadouts have been identified, with a plethora of GPS- and laser-guided munitions reflecting a desire for flexibility and the potential of Israeli ground-based target designation. Furthermore, the employment of EW via airborne jammers and electronic attack systems (designed to confound adversary radars) is essential to enabling destructive strikes by supporting aircraft. The IDF's airborne EW platforms are hard to identify, but its F-35I and F16I are known to carry domestic EW systems, and Israel is known as a world leader in EW defense technology. In contrast, Russian EW pods are often operated in an autonomous mode that only provides protective jamming rather than electronic suppression of enemy GBADs.

On the other hand, the VKS did not demonstrate that it combined suppressive weapons, like ARMs, with weapons better suited to destroying the target—especially precision-guided munitions. Russian aircraft were observed using a variety of ARMs from the Kh-31 series launched primarily from Su-35S multi-role fighters, Su-30SM multi-role fighters, and Su-34 strike fighters. At the level of the individual aircraft, Russian airframes were rarely observed loaded with both ARMs and other air-to-surface weapons, reflecting an insufficient weapons combination for both suppression and destruction of adversary GBADs. In addition, Russian aircraft frequently flew without EW pods during the first three days of the conflict. Russian strikes were primarily conducted by single aircraft, which is consistent with the VKS's combat experience in Syria but limits an air force's ability to combine suppressive and destructive effects.

Russia's ability to combine arms was further limited by problems of fratricide, a sign of ineffective command and control. Russian EW caused so many problems with communications between poorly equipped Russian ground forces that Russia was forced to scale back its EW efforts against Ukrainian GBADs. Russian fratricide also reflects a difficulty coordinating the activities of different combat arms, a vital task for modern force employment. Russian pilots were repeatedly shot down by their own GBADs. In contrast, suffering ground-to-air friendly fire prompted Ukraine to adapt its force employment by placing Man-Portable Air-Defense Systems (MANPADS) operators in its mobile air defense teams, which integrated them into air force and air defense planning cycles and communication networks and reduced fratricide by MANPADS operators.

Underlying many of these differences in force employment are likely major differences between IAF and VKS training, as previously discussed. Russian pilots receive far less training than their Israeli counterparts. VKS pilots fly fewer than 100 training hours per year, while Israeli pilots likely fly at or above the NATO minimum of 180 flight hours per year.79 Russia's training is also less realistic than Israel's, focusing on simple tasks rather than complex operations.

Ukrainian adaptation also played a role. Ukraine's employment of a mobile, dispersed GBAD force allowed it to deny Russia air superiority. Ukraine rapidly relocated most of its mobile air defense systems shortly before the first round of Russian long-range strikes. It then dispersed its Buk units, which had previously operated as divisions, into small air defense teams. Ukraine's dispersal and mobility allowed it to employ new "shoot-and-scoot" tactics with its mobile Buk systems, deploying them as individual "pop-up threats" rather than as batteries. Integration of Ukrainian MANPADS operators into the air-defense teams also allowed the Ukrainians to force Russian pilots to choose between flying high and being targeted by radar-based GBADs or flying low and facing Ukrainian MANPADS missiles.

This mobility allowed Ukraine's GBADs to survive and eventually recover, playing a role in the Russian failure to convert suppression into destruction: Ukraine was able to disperse its mobile systems in the hours before Russian strikes began, saving about 90 percent of them from destruction. Ukraine's dispersed force employment required tradeoffs—Buk units were cut off from their battalion-level surveillance and targeting assets—but the new force structure allowed for greater geographic coverage and survivability. Ukraine's Buks quickly emerged as the backbone of the Ukrainian air defense system, deploying near the front lines to push the VKS out of

Ukrainian airspace.

Implications

This section outlines lessons for military forces seeking to achieve air superiority or denial. Most lessons merely reinforce enduring principles of war, but Israel's use of special operations to disrupt and destroy Iranian GBADs has novel operational implications.

Combined Arms

Both examples reinforce the importance of combined arms at the strategic, operational, and tactical levels. Combined arms work in two ways: (1) the strengths of one system compensate for the weaknesses of another, and (2) enemies trying to evade one system become targetable by another. Ukraine benefited from the first effect when its combat aircraft took over the air defense mission from its GBADs during the first few days of the conflict. Iran, with its ancient and incapable air force, did not. Ukraine also benefited from the second effect when it integrated its MANPADS operators into air defense teams with mobile Buk systems: Russian pilots sought to avoid radar targeting by flying low, which exposed them to targeting by MANPADS missiles.

Israel likely also benefited from combined arms, albeit more clearly at the tactical level. Israeli weapons loadouts and investments in EW systems suggest that it combined multiple modes of attack in which kinetic and electronic systems took advantage of different weaknesses of Iranian systems.

Similarly, Russia began to benefit from the effects of combined arms and long-range artillery as it integrated Orlan-10 UASs into its efforts, but by then it was too late to take full advantage of the initial suppression of Ukraine's GBADs.

Qualitative Superiority

The quality of technology and personnel differed across the campaigns, and both likely made a big difference. Israel almost certainly benefited from enormous technological superiority over Iran, particularly in its ISR, EW, and PGM capabilities. Ukraine also probably benefited from its significant investments in upgrading its GBADs. However, a lack of granular data on what systems were used and how they performed on the battlefield limit the conclusions that can be drawn regarding technological superiority.

Human capital, however, clearly proved critical. Russia's technological superiority was insufficient to overcome training deficiencies, and aggressive Ukrainian pilots were able to blunt the efforts of their better-equipped but under-trained VKS counterparts. Ukraine's GBAD operators also proved capable of operating independently as pop-up threats, which required confidence and initiative that can only be effectively taught through realistic training.

Flexibility

Ukraine's dispersion of its mobile Buk systems likely made them more survivable, although Russia's failure to employ large, heterogenous air strikes or order rapid follow-on strikes makes attributing Ukraine's success entirely to its force employment impossible. Operating its Buk launchers as individual pop-up threats may have failed against larger formations that employed a greater mix of strike and countermeasure assets, like those employed by Israeli forces. Against the types of formations envisaged by Western air superiority doctrine, a more traditional integrated air defense system may have performed better. Militaries can hedge against this uncertainty by prioritizing the development and acquisition of mobile systems that can operate either in a coordinated battery or as pop-up threats and training their crews to operate in both modes.

This type of flexibility requires investment. Ukraine's ability to disperse its Buk systems depended in part on the Buk's use of transporter erector launcher and radar (TELAR) vehicles. TELARs incorporate targeting and launch capabilities into a single vehicle, whereas other types of launchers cannot operate without accompanying radar vehicles. Many militaries—like Taiwan's, for example—operate no long- or medium-range TELARs, which limits the operational flexibility of their GBADs.

Flexibility also matters for attackers. Israel's use of mixed strike packages suggested a desire for flexibility. In contrast, the VKS demonstrated little operational flexibility. Russia's apparent practice of striking targets in the order received and corresponding lack of dynamic targeting increased the effectiveness of Ukraine's dispersed pop-up tactics. VKS pilots did not demonstrate that they were able to react effectively on the fly to the sudden emergence of a new threat or opportunity.

The VKS also proved inflexible in another important way: Russia's command structure limited its ability to pursue its air superiority mission to the greatest extent possible. Subordinating air units to ground command and the priority given to close air support in Russian practice diverted VKS resources from the air superiority mission when Ukraine's air defenses were at their weakest. The priority given to ground operations also forced the VKS to limit its use of EW against Ukrainian systems, reducing the effect of combined arms.

Intelligence

Effective air superiority requires aggressive, continuous intelligence collection and responsive dissemination of target data, most notably in terms of threat assessments for the supported operational assets. Russia's failure to update its intelligence during the lead-up to the attack likely limited the efficacy of its initial strikes. In contrast, Israeli intelligence maintained effective custody of these targets through a variety of intelligence sources, further preparing the operational environment to overwhelm their opponents.

Suppression of enemy air defense must always be followed by rapid cycles of battle damage assessment and follow-up strikes until they are confirmed destroyed or contact with the enemy is lost, although this need is not unique to air superiority operations. Russia's failure to conduct follow-on strikes when Ukrainian GBADs were suppressed allowed Ukrainian air defenses to reconstitute after a few days. Rapid cycles of intelligence processing for air or missile strikes require pushing analysis capability and targeting authority down the chain of command.

Closely related to the importance of intelligence is the importance of surprise. The United States warned Ukraine of Russia's intent to invade, allowing the Ukrainian armed forces to relocate its mobile GBADs before Russian strikes arrived on target. Israel achieved complete surprise over Iran, which did not mount any effective defense. While hardly a novel lesson, the two conflicts reinforce the desirability of achieving surprise, the need to maintain operational security, and the value of warning intelligence.

Special Operations

Special and intelligence operations have a surprisingly large role to play in modern air superiority operations. Israel effectively demonstrated that these operations can attack an air defense system from unexpected and poorly defended directions, thus enabling conventional forces. Air planners should coordinate with organizations responsible for covert and clandestine operations, which will require overcoming bureaucratic barriers in many militaries. As they are integrated into conventional air superiority plans, irregular operations should not depend solely or primarily on psychological measures to suppress or disrupt adversaries' air defense (or more general military and political) systems. While information operations or the psychological effects of violence can support destructive or suppressive operations, they cannot replace them.

Air defenders cannot ignore these types of operation. GBADs must be protected from close-in attacks by special operations forces. Drone attacks such as those conducted by Israel against Iran are repeatable, meaning that other countries can replicate them to an extent, even if the networks and systems they require are used up in the attack. Local counter-UAS bubbles will be a vital part of integrated air defense systems in the future. However, these attacks are unlikely to be limited to precision weapons: Irregular forces could also conduct EW attacks, plant cyberweapons, or engage in old-fashioned sabotage to suppress or destroy air defense systems. Counterintelligence will play a major role in defending against these types of operation, but relying entirely on detecting covert operations puts too many eggs in one basket and will likely prove increasingly vulnerable as advancements in artificial intelligence reduce the need for human involvement in UAS operations. Individual air defense sites should be hardened against cyber, electronic, and physical attacks originating within the system's lethal envelope.

Conclusion

Despite the differences between the Ukrainian and Iranian contexts, several lessons for air defense and air superiority efforts are evident from Israel and Russia's air campaigns. Israel succeeded where Russia failed because it let its air forces maintain their focus on achieving and maintaining air superiority, effectively integrated destructive special operations into its preparation of the environment, rapidly updated its battlefield intelligence, and procured, planned, and trained for offensive air superiority operations for years. Ukraine also contributed to its own success through the courage and aggression of its fighter pilots and the adaptability of its GBAD systems.

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Chinese Team Unveils Smart, Super-Tough Coating for Stealth Aircraft

Zhang Tong | 24 October 2025

Source: SCMP | https://www.scmp.com/news/china/science/article/3330025/chinese-team-unveils-smart-super-tough-coating-stealth-aircraft?module=top_story&pgtype=homepage

China has developed a flexible, durable aircraft coating that absorbs radar waves, potentially closing a critical technological gap and redefining the future of aerial stealth.

A study published on October 14 in Advanced Materials details a scalable, flexible and ultra-thin (0.1 mm) metasurface capable of withstanding temperatures up to 1,000 degrees Celsius (1,832 degrees Fahrenheit).

The material features tunable impedance, making it suitable for aerospace electromagnetic wave absorption.

It shows balance between performance, durability and manufacturability, and could have potential applications in fighter aircraft, according to the paper.

The research was led by Cui Guang and Liu Zhongfan from Peking University, along with Wang Huihui from Peking University of Technology and Li Maoyuan from Harbin Engineering University.

Liu's team had previously discovered that chemical vapour deposition could be used for large-scale graphene production.

Building on this, the team deposited graphene directly onto a silica fabric substrate, forming a graphene@silica fibre membrane (G@SFM). The resulting material resembles a soft cloth but combines lightweight properties, flexibility and resistance to extreme heat.

However, the material's uniform surface was initially ineffective at dissipating electromagnetic waves. To address this, the team applied a subtractive laser patterning technique, creating a metasurface with tunable surface impedance that enabled effective electromagnetic wave absorption.

The final material exhibits an ultra-thin profile (~0.1 mm), low surface density, excellent flexibility and tunable sheet resistance ranging from 50 to 5,000 ohms per square.

It is also stable, maintaining consistent wave-absorbing performance after exposure to 600 degrees Celsius in air for five minutes and long-term heating at 1,000 degrees in a vacuum. Under high-speed airflow of 200 metres per second, the material experienced less than 1 per cent loss, with the metasurface pattern and sheet resistance remaining intact.

These properties make the material particularly suitable for the thermal conditions encountered by high-speed aircraft.

"Integrating this metasurface directly into an aircraft's thermal insulation layer can reduce radar reflection to -42 [decibels] without adding significant weight or altering the aircraft's structure," according to the researchers.

They said the material "not only offers structural and thermal stability for aerospace use but also holds potential for broader applications, including satellite payload protection, stealth surfaces for defence platforms and electromagnetic shielding for high-temperature electronics in extreme industrial or space environments".

The laser patterning strategy can also be extended to millimetre-wave and terahertz frequencies, supporting next-generation wireless communications, space-based sensing and adaptive stealth systems.

This breakthrough stands in stark contrast to known challenges faced by United States stealth aircraft. During the 2025 Changchun Airshow, spectators observed maintenance personnel wiping the surface of a J-20 fighter with a dust-free cloth – suggesting the aircraft's radar-absorbing coating is both weather resistant and easy to maintain.

Meanwhile, the maintenance of US stealth fighters remains a major concern. The F-22, the world's first fifth-generation fighter, uses an iron-based radar-absorbent coating that, while effective, is fragile and prone to peeling because of airflow erosion or rust. It is widely reported that F-22s must be housed in specialised hangars with controlled temperature and humidity.

In July, photos of a rusty F-35C aboard the USS Carl Vinson went viral online. One possible cause is the iron content in the F-35's stealth coating, which is vulnerable to oxidation in the aircraft carrier's high-salinity, high-humidity environment. Once the coating is damaged, corrosive salt spray can penetrate, accelerating internal rust and creating a vicious cycle.

A US Department of Defence report noted that the F-35A incurred operating costs of US$28,500 per flight hour, second only to the F-22A's US$33,500.

China's research in next-generation stealth materials continues to advance across multiple fronts.

In June, a team led by Gui Xuchun at Sun Yat-sen University developed an MXene film just 2.25 micrometres thick.

It achieved an electromagnetic shielding effectiveness of 45 decibels in the gigahertz frequency band and 59 decibels in the terahertz band, while also exhibiting an extremely low infrared emissivity of 0.1 – close to that of aluminium – enabling excellent infrared stealth capability.

Jet-Powered Bombs and Planes-Turned-Missiles: Ukrainian and Russian Militaries Improvise and Adapt in a Battle of Wits

Tim Lister, Victoria Butenko and Kosta Gak | 25 October 2025

Source: CNN | https://edition.cnn.com/2025/10/25/europe/ukraine-russia-militaries-improvise-missiles-intl

An apartment in a Moscow suburb damaged by a Ukrainian drone on Friday morning. (Olesya Kurpyayeva/AFP/Getty Images)

Improvise and innovate have become the watchwords for both the Russian and Ukrainian militaries as they try to outwit each other on the ground, at sea and in the air.

Several recent developments illustrate this constant evolution of tactics and weaponry: a new Russian jet-powered bomb, the Ukrainian use of light planes as long-range 'suicide bombs,' and a fresh generation of maritime drones.

Both countries are exploiting AI, robotics and unmanned systems at a high tempo.

But some innovations are remarkably low-tech.

As night fell on one Ukrainian airfield earlier this month, a small group of men assembled a pilot-less light plane for a 2,000-kilometer (1,243-mile) mission deep into Russia. Its target was in the Russian industrial city of Dzerzhinsk, about 230 miles east of Moscow.

Strapped to its undercarriage was a very basic bomb.

Hours after the single-engined plane took off into the night sky, a large fire was reported at an explosives factory in Dzerzhinsk that makes shells for the Russian military.

The program was created by an aviation enthusiast with the call-sign Goronych and converts single-seater planes into rudimentary but effective long-range missiles. Instead of a pilot's seat, there is an additional fuel tank and batteries that power navigation and communication systems, according to a report by the Ukrainian outlet Babel that CNN has confirmed.

Goronych and his group are now integrated into the 14th regiment of Ukraine's special operations forces, who spoke with CNN about their work. On Wednesday, according to the Ukrainian military, they were involved in an attack on a mechanical plant in the Russian city of Saransk – nearly 800 kilometers (497 miles) from the Ukrainian border – where detonators and mines are manufactured.

The Goronych project represents one of dozens of adaptations made by both sides as the conflict has worn on – especially using light aircraft and drones.

In September, the Ukrainian military's chief of staff, Oleksandr Syrskyi, said light aircraft mounted with machine guns were proving effective in intercepting Russian drones and the military would consider buying more.

The Russians recently began deploying small planes equipped with machine guns in occupied territory to take down Ukrainian drones on their way to targets in Russia.

Their mistake was profiling them on television.

The Ukrainian Security Service established where the planes were based and said on Tuesday that it had "neutralized two small aircraft that the occupiers stationed at airfields and used to shoot down Ukrainian long-range drones."

Not all innovations are as basic.

In recent weeks, Russia has begun deploying a new jet-powered guided bomb, adapted from its huge stocks of old "free-fall" bombs, according to Ukrainian Defense Intelligence (DI).

"The range and combat radius of such bombs will be approximately 200 kilometers (124 miles)," said the deputy head of DI, Vadym Skybitski, in a statement.

The Russians had already been converting Soviet-era bombs into glide munitions with a range of some 80 kilometers (50 miles), allowing aircraft to fire them while staying well clear of Ukrainian air defenses. On just one day last week, nearly 300 such bombs were fired against Ukraine. The daily average is just over 100, according to the Ukrainian General Staff.

The new longer-range variant – dubbed the UMPB-5 – has already been used in strikes against Kharkiv in northeastern Ukraine in recent days. A Russian aviation blogger posted on Monday that the weapon was "already being used against the Ukrainians… Now they will put it into production and things will really heat up."

The Ukrainians have pioneered the development of maritime drones, which have been especially effective against Russia's Black Sea fleet. This week, the Security Service (SBU) unveiled the latest generation.

One of them was used in an attack on the bridge linking Russia and occupied Crimea in June, the SBU said. The updated models are capable of traveling more than 1,500 kilometers (932 miles), and can carry up to 2,000 kilograms (4,409lbs) of explosives. They can also carry a multiple rocket launcher system.

In the early days of the conflict, the Ukrainian military was much more agile than Russian forces in terms of adapting tactics and equipment. But over time, said defense analyst Dara Massicot, "Russian units grafted protective armor onto vehicles, learned new styles of camouflage, and adopted small-unit assault tactics, among many other adaptations."

The Russian Defense Ministry also set up an elite drone unit called Rubikon, "which experiments with different types of tactics that now inform how other UAV units are instructed," Massicot wrote in Foreign Affairs.

For all its innovation and a surge in domestic production of drones and missiles, Ukraine still needs a constant pipeline of weapons from its allies. Russian barrages of missiles and drones – often several hundred in one night – have again underlined its shortfall in air defenses.

Zelensky renewed calls for Western-made defenses in the wake of a deadly attack overnight on Friday into Saturday, which killed two in capital Kyiv. Ukraine is "paying special attention to the Patriot systems, so that we can protect our cities from this horror," he said.

Russia is moving toward producing more than 6,000 Shahed-type drones each month, Ukraine's Defense Intelligence told CNN in September.

That's just one reason why Ukraine wants longer-range missiles – to take the war to targets such as drone factories deep inside Russia. But US President Donald Trump says that, for now, providing Tomahawk cruise missiles is off the table.

Kyiv is now pinning its hopes on Europe to beef up its capabilities. "Everyone who is now helping Ukraine with air defense systems and (the) missiles for them is protecting lives," Ukrainian President Volodymyr Zelensky said Wednesday.

"And everyone who helps Ukraine with long-range capabilities will bring the end of the war closer," he added.

Zelensky said he anticipated "a good and, in many ways, completely new agreement on our defense capabilities" in meetings with European allies this week.

But, with most weapons production pipelines measured over years rather than months, rapid improvisation has an important role on the battlefield.

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New Radar and Missile Tech have 'Flattened the Earth,' Making even Low-Flying Jets Easy Targets, Royal Air Force Officer Warns

Sinéad Baker | 25 October 2025

Source: Yahoo.com | https://www.yahoo.com/news/articles/radar-missile-tech-flattened-earth-112701588.html

Ukraine and Russia's heavy air defenses have prevented either side from taking control in the air. DANIEL MIHAILESCU/AFP via Getty Images

New radar and missile technology have resulted in a "flattening of the earth" that puts even extremely low-flying aircraft at much higher risk, a Royal Air Force officer said this week.

Air Vice-Marshal James Beck, the RAF's director of capabilities and programs, said that when he was flying the Tornado multirole combat aircraft in the early 2000s, it was still an "underlying assumption that ultra low flying would allow a formation the ability to penetrate deep into enemy territory without being detected by their integrated air missile defense systems."

The assumption was that the hostile radars could not see through the ground, and this "underpinned our tactical thinking for many decades," he said, addressing the UK's Royal United Services Institute on Monday.

Terrain-masking was long a credible tactic, with fighters flying low and fast beneath the radar horizon and using the earth's curvature and ground clutter to evade line-of-sight radars. The approach made sense against legacy radars and surface-to-air missile systems. Advancements, however, are making low-level penetration insufficient on its own.

New radar and missile developments have made the classic approach "obsolete," Beck said, characterizing the shift in technology as tantamount to a "flattening of the earth."

He pointed to advances in radar technology, like the Active Electronically Scanned Array (AESA) radar, which has electronically steered beams to detect targets and allows crews to track multiple targets. Beck also highlighted the challenge of newer Over-the-Horizon (OTH) radars that can do just what the name implies and see beyond the curve of the earth. And then there are also the "all-pervasive abilities" of airborne surveillance aircraft.

Detection ranges have jumped from hundreds of nautical miles to thousands, he said, adding that the ranges of both surface-to-air and surface-to-surface missiles are also growing rapidly.

Gen. James Hecker, commander of US Air Forces in Europe, said previously that his "number one priority throughout NATO on the air side, is the counter-A2AD missions — so counter anti-access, area-denial missions." The threats in this space are expanding.

Beck said these developments will soon make it far more difficult for air forces to enter an enemy's battlespace. Militaries use what's known as anti-access, area-denial strategies — layers of radars, missiles, and sensors — to keep adversaries out.

Those restricted zones are already vast — "measured in countries," Beck said — and could expand dramatically. Within the next decade, he predicted, "they will likely be measured in continents."

A big challenge

The flattening of the modern battlespace, Beck warned, will make it increasingly difficult for aircraft to penetrate deep into enemy territory without being detected or engaged.

That's a problem. Seizing control of the air and penetrating deep to knock out command nodes, logistics hubs, and missile sites far behind the front line are critical to victory.

The war in Ukraine, a grinding attritional fight chewing up equipment and troops, "continues to show us what happens if we fail to master control of the air from the outset," Beck said.

"Indeed, the longer the conflict reigns, this lesson becomes ever more compelling."

Neither Ukraine nor Russia has been able to seize control of the air as they are stymied by strong air defense networks that threaten anything flying. There have been numerous videos of Ukrainian combat aircraft flying low, hugging the earth and only popping up to launch munitions, but we're not seeing penetration flights into enemy-controlled airspace.

Both sides are, however, lobbing drones and missiles deep behind the lines, highlighting the importance of maintaining robust air and missile defense systems, especially given adversary capabilities have, as Beck said, "advanced dramatically."

"The pace of change continues to accelerate, with an increasing range of state and non-state actors posing new challenges," he said.

Demands of Future War

Taking advantage of new technologies to keep ahead of the curve will be key as the battlespace shifts.

"As a first step," Beck shared, the UK "will prioritize upgrading our existing command and control capabilities to maximize the effectiveness of current systems and lay the foundation for future enhancements."

He added that the UK would also capitalize on advances in sensor technology, including surface, airborne, and space-based sensors, "to extend detection and tracking ranges, increasing opportunities to engage and defeat threats through a system of layered defenses." The aim is also to extend the range of both active and passive defensive systems, he said.

Particularly important work when it comes to being able to penetrate heavily defended airspace is the development of sixth-generation aircraft, like the US Air Force Next Generation Air Dominance program's F-47 or the Global Combat Air Programme (GCAP) that the UK, Italy, and Japan are working on.

Beck said that right now fifth-generation aircraft like the F-35 Lightning II Joint Strike Fighter are the bare minimum for getting the edge in a modern air war. Sixth-gen fighters will need to bring advanced stealth, among other capabilities.

Without that full-spectrum stealth, aircraft "will be unable to enter an opponent's A2AD bubble to a level that it would be able to deliver meaningful effect," he said.

He said sixth-generation aircraft will need to carry out the deep strikes that are becoming increasingly difficult and “detect, select, and prosecute targets that are operating in or on the far side of an opponent's integrated air missile defense system.”

The UK's air staff chief, Beck said, "has made it very clear that control of the air is the thing that we must master above all else."

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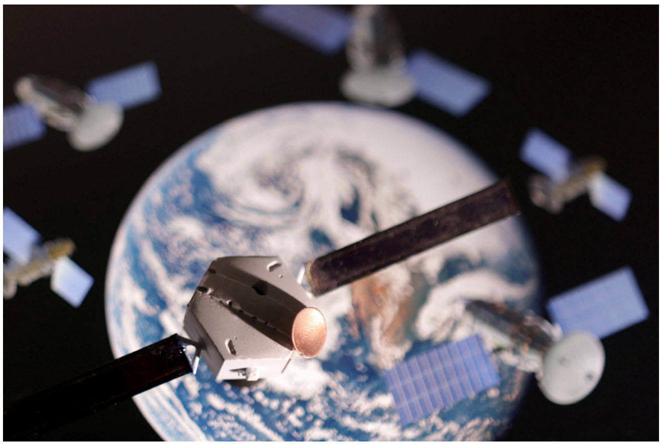
Space

Why Cyber Resilience in Space is Essential for Economic Security

Bushra AlBlooshi, Heba Ahmad and Hoda Al Khzaimi | 06 October 2025

[Source: Weforum | https://www.weforum.org/stories/2025/10/why-cyber-resilience-in-space-is-essential-for-economic-security/](https://www.weforum.org/stories/2025/10/why-cyber-resilience-in-space-is-essential-for-economic-security/)



Increased democratization in access makes building cyber resilience in space essential.

Image: REUTERS/Dado Ruvic/Illustration

From international finance and climate monitoring to navigation and humanitarian assistance, satellite services from space are now woven into the fabric of modern life. Valued at over $630 billion in 2023, with projections exceeding $1.8 trillion by 2035, space has shifted from frontier to foundational infrastructure.

Yet as space becomes indispensable, it is increasingly contested. Cyber disruptions, jamming attacks and geopolitical manoeuvres highlight a fragility that coexists with rapid innovation.

The expanding footprint of new space systems and businesses, with hundreds of new start-ups and 10s of billions in investment in recent years, has created unprecedented opportunity and also multiplied vulnerability. These pressures are converging and securing our global space infrastructure has become imperative for innovation and stability.

Why our Space Infrastructure is at Risk

Space systems operate as a "system of systems": satellites in orbit, ground control stations, communication links and user devices. Each represents a potential point of failure and a breach in one can ripple across others.

The ground segment, often built on conventional IT systems, is especially vulnerable. In 2022, the KA-SAT cyberattack disrupted over 40,000 terminals across Europe, impairing military and emergency communications.

In July 2025, a Starlink software failure caused a global outage affecting millions of users. Both events demonstrate how software vulnerabilities can cascade into space and terrestrial disruptions.

The link segment is also exposed. Global positioning system (GPS) jamming and spoofing have disrupted aviation across Europe, affecting thousands of flights and highlighting the fragility of navigation services.

Commercial satellite operators daily fight off attacks; despite the use of varying levels of encryption and other secure design approaches, management of supply chains and application of standards, satellites and space platforms are often inadequately protected as threats evolve.

In addition, legacy satellites, often designed decades ago without cybersecurity considerations, can remain active for 15 years or longer. More than 1,700 satellites launched before 2000 are still operational, many of them critical and costly to replace but impossible to patch or retrofit. Their very longevity now makes them fragile assets.

The New Gold Rush and Security Deficit

Access to space is increasingly democratizing. From start-ups to governments, space actors are launching mega-constellations at record speed. By 2024, more than 11,500 active satellites orbited Earth, with 80% operated by commercial entities. These constellations fuel economic opportunity but also create a vastly expanded cyberattack surface.

Cost pressures exacerbate vulnerabilities: commercial providers often rely on off-the-shelf components and open-source code, efficient but not necessarily designed for a highly contested cyber environment.

The blurred boundary between commercial and military space raises further risks. Commercial satellites have been used to support military operations for decades.

Today, constellations such as Starlink have been leveraged in conflict zones, potentially becoming military targets. Governments increasingly depend on these systems, which may not meet desired software and operating standards, as cyber-attacks on space systems become more common.

Emerging technologies add both promise and complexity. Quantum communication satellites (e.g. China's Quantum Experiments at Space Scale mission), space-based solar power demonstrators in Europe and Japan, and artificial intelligence (AI) driven satellite constellations for Earth observation represent potentially transformative advances but each adds new dependencies and potential vulnerabilities.

Governance and Regulatory Gaps

The pace of commercialization has outstripped cyber governance in space, as it has terrestrially. The Outer Space Treaty (1967) provides broad principles of peaceful use but is silent on cybersecurity or digital resilience.

Multiple United Nations bodies and other organizations have sought to develop space cyber frameworks and standards but today, no international framework fully covers the cyber integrity of space systems.

International agreement is particularly important regarding command and control of space systems, to prevent interference with operations and risks such as collisions, which can cause debris fragments that can harm many other satellites, with long periods of risk.

Instead, regulations remain fragmented across jurisdictions, producing uneven standards and exposing shared assets to systemic risk. These gaps are particularly concerning in light of the importance of sustainability and operational safety in space, which the Global Future Council on Space Technologies has highlighted.

Cybersecurity is not peripheral to these goals; it is foundational. Without cohesive global standards, space infrastructure risks becoming a “patchwork domain” where safety, sustainability and digital resilience are undermined simultaneously.

Building Resilience Through Collaboration

Securing orbital systems requires an integrated approach that combines technology, governance and international coordination. This requires a systematic consideration of critical pillars, such as security by design, where cyber resilience must be built into satellites and other space assets from the first line of code to deployment.

Additionally, systems should include zero-trust architecture where every user, device and connection is continuously verified. Supply chain security is vital, where compromised hardware or firmware during manufacturing can endanger billion-dollar constellations.

Finally, placing digital resilience over prevention dictates that we assume breaches will occur; hence, systems must be designed to withstand, adapt and recover. Governments hold leverage through procurement and regulation, while industry agility remains vital.

National government actors will remain chiefly responsible for enforcement and will benefit from international benchmarks they can draw on and incorporate into regulation and policy.

Models such as the Space Information Sharing and Analysis Center provide platforms for industry and government to collaborate on real-time threat intelligence sharing. On the global stage, adapting norms from cyber diplomacy, such as those developed in the UN Group of Government Experts and Open-Ended Working Group, can foster common standards for responsible behaviour.

Securing Cyber Resilience in Space

Space has become a contested environment. It is a domain where failure would reverberate across economies, societies and security systems worldwide. Its protection cannot be treated as optional or secondary.

As Carissa Christensen, CEO of BryceTech and member of the World Economic Forum’s Global Future Council on Space Technologies, emphasizes:

“Space is no longer peripheral to our economy or security. It is embedded in everything we do. With enhanced cybersecurity, transparency and trust in space systems, space can remain a driver of prosperity and stability.”

The vulnerabilities are clear, and so is an important path forward: embed security at the DNA level of designing the space paradigm, enforce accountability across supply chains and build governance architectures that treat space assets as critical infrastructure.

These measures are not luxuries. They are prerequisites for stability.

Governments, industry and the global community must act now to ensure that space remains a trusted enabler for cooperation, innovation and resilience. The alternatives are fragmentation and systemic fragility that would compromise not just the orbits above us but the world below.

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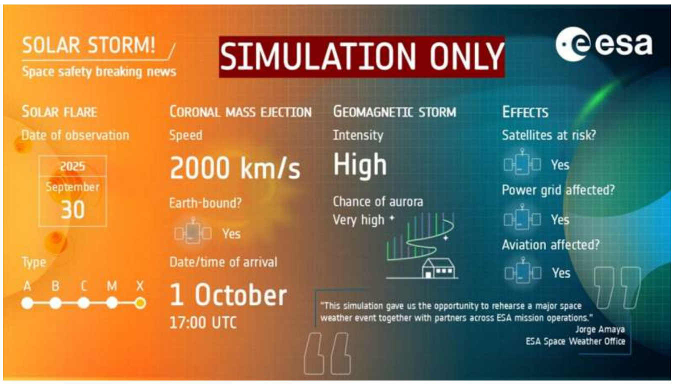
Simulating Solar Storms for Satellite Operator Training

Andy Tomaswick | 25 October 2025

[Source: phy.org | https://phys.org/news/2025-10-simulating-solar-storms-satellite.html](https://phys.org/news/2025-10-simulating-solar-storms-satellite.html)



Space weather simulations exercise at ESOC. Credit: ESA

Threats from space aren't always obvious, but statistically, it's only a matter of time before one of them happens. One of the most concerning for many space experts is a massive solar storm, like the one that literally lit telegraph paper on fire when it hit back in 1859.

In the last 150 years, our technology has improved by leaps and bounds, but that also means it's much more susceptible to damage if another event like the "Carrington Event," as the storm in 1859 is called. Estimates for potential damage range into the trillions of dollars, with full economic recovery taking well over a decade if something isn't done to mitigate the damage beforehand.

As part of that preparedness, the European Space Agency (ESA) has started requiring the operational crew of new satellites, which would be on the frontlines of any solar storm catastrophe, to simulate how they would handle such an event, as described in a recent press release focused on one of those simulations.

To be blunt, the best they can do is damage control. There is no good outcome for a satellite in the event it is in the direct path of a solar storm. The most it can hope for is to get through the event still functional and with only a little bit less fuel than intended, due to using that fuel to enhance its orbit-keeping as the atmosphere swelled from the storm and slowed the satellite down.

In this particular example, the Sentinel 1-D team had to deal with a simulated solar storm just after the planned launch of their spacecraft, which is currently scheduled for November 5th. Sentinel 1-D is part of ESA's Copernicus Programme to monitor Earth's surface in radar and provide updated maritime and land conditions. The simulation its team had to go through was laid out in three stages.

First, the satellite was hit by an X45-class solar flare, which was traveling at the speed of light, with basically no warning for the operations team whatsoever. That flare, which was comparable to one around Halloween 2003 that knocked out power to some people on the ground as well as disrupted GPS accuracy, causing flights to be rerouted, especially those that were flying over the poles. In this simulated case, the solar flare portion of the storm knocked out GPS once again, making it difficult for the Sentinel 1-D team to position where they were.

A few minutes after the solar flare arrived, the satellite was bombarded with high energy particles traveling near the speed of light. While the appearance of the solar flare allowed for some warning that this would occur, it is difficult to defend against these particles, which have a tendency to flip "bits" in critical pieces of satellites like electronic memory and communications systems. This could cause permanent damage to the system, corrupting its memory of frying part of its circuitry.

But that isn't the largest danger—about 15–18 hours after the particle storm, the bulk plasma of a coronal mass ejection would arrive. This caused a swelling of Earth's atmosphere by up to 400%, creating massive drag for the newly launched satellite.

But also, critically, for all other satellites in its neighborhood who might not have enough fuel to deal with that sudden increase. This created a series of choices for the Sentinel 1-D team—how to best avoid collisions in this newly chaotic environment. The probabilities of those collisions were changing so rapidly that it's hard to make a well-informed choice—and every choice of what to avoid or to ignore could have impacts on other potential collisions later on.

Such simulations offer the operational team a chance to understand first-hand what those choices are, and what the realistic expected outcome of such a scenario would be. The press release didn't report on how the Sentinel 1-D team fared as a result of the simulation, but again, the best they could have hoped for was damage mitigation.

The simulation was held at ESA's mission control center (ESOC) in Darmstadt, Germany, and represents what will soon become standard practice for future satellites going forward, as the agency begins to focus more on space safety. Whether other space-oriented organizations take the same precautionary approach might one day determine how much of our orbital infrastructure survives a catastrophic event which will, one day, almost certainly happen.

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How Spacefaring Nations could Avoid Conflict on the Moon

Simonetta Di Pippo | 21 October 2025

Source: phy.org | https://phys.org/news/2025-10-spacefaring-nations-conflict-moon.html

Credit: NASA

In the 1960s, Frank Sinatra's song "Fly Me to the Moon" became closely associated with the Apollo missions. The optimistic track was recorded in 1964, when US success against the Soviet Union in the moon race was not assured.

Nevertheless, when the crew of the Apollo 11 mission landed first on the lunar surface in 1969, the Sinatra song became an appropriate tune for an era when, in the West, anything seemed possible.

In the 21st century, the exploration of the moon will take a different form. Several countries want to go there and stay. The US, China and international partners on both sides have plans to establish permanent bases on the lunar surface—raising the possibility of conflict.

The bases will be located at the south pole of the moon, which has valuable resources such as abundant water in the form of ice. This ice, locked up in permanently shadowed craters, could be turned into water for use by lunar bases and into rocket fuel to support ongoing exploration and the people living there. The moon may also have valuable minerals, such as rare earth metals, that countries may want to extract.

But such resources will be limited, as are suitable sites for landing and building lunar bases. The potential for conflict between nations in space is not beyond the realms of possibility.

However, there are measures that can be taken to ensure that the future is a cooperative one. So a song as optimistic as Fly Me To The Moon could serve as the soundtrack to this new age in exploration, just as it did in the 1960s and 70s.

International treaties could be the solution, together with a willingness of countries to operate responsibly. The Outer Space Treaty of 1967 says that space is not subject to national appropriation by claim of sovereignty, or by means of use or occupation. At the same time, Article I of the treaty considers space as a global common, and states that the exploration and use of space is for all nations, including its resources.

A vital question is whether the moon's water ice be used without some level of appropriation.

Moon Agreement

The Artemis Accords, a set of guidelines initiated by the US, is a bottom-up attempt to establish a common behavior. Section 10 of the Artemis Accords says that the "extraction of space resources does not inherently constitute national appropriation under Article II of the Outer Space Treaty".

It also proposes the use of temporary "safety zones" around operations to extract resources. Signatories to the Artemis Accords must provide notification of their activities to other nations and commit to coordinating to avoid harmful interference.

However, these safety zones are highly controversial because they could be seen as a breach of the Outer Space Treaty's non-appropriation principles, to say the least. To some, these zones could create de facto ownership rights over space resources.

As of now, 56 countries have signed the Artemis Accords. Thailand and Senegal have signed the US-led accords and are also involved in China's lunar base project. As such, these nations provide a bridge between the two programs and hope for collaboration.

The Moon Agreement, adopted in 1979 by the UN, also governs how Earth's natural satellite should be used. There are a lot of interesting features in this treaty, including a call for transparency, with requirements for states to share information about their lunar activities, and an international effort to manage lunar resources.

The aim is to build confidence between signatories to the agreement. Like the Outer Space Treaty, it strictly prohibits the national appropriation of space resources.

A major impediment is that neither China, nor the US nor the Russian Federation have signed up. However, in my view, the Moon Agreement provides the best framework for the future—without further treaties or accords. Nations just need to use it. And if one or two articles need a change, they should be changed.

New Era

The world is standing on the verge of a new age in lunar exploration. Whether the US or China arrive there first, there is a new will to establish a permanent presence on Earth's natural satellite. China, along with about ten countries, is planning a base called the ILRS (International Lunar Research Station). NASA, meanwhile, is developing a lunar station called Artemis Base Camp.

These will take some time to build, but nations are already off the starting blocks. NASA's Artemis II mission, which will carry four astronauts on a flyby of the moon, is set to launch in February 2026. On September 24 this year, the US space agency also announced a new class of astronauts who are likely to fly on future missions to the lunar surface.

These developments show that there is the potential for a more equitable future in space than the one we have experienced in the past. I couldn't help noticing, for example, that of the 10 newly selected astronauts, 60% are women, which is a first.

China recently completed a test of its crewed lunar lander, Lanyue. Its ILRS lunar base project has signed up nations without a long track record in human space exploration.

So how can countries ensure that they capitalize on the promise of a cooperative future in space and avoid transferring existing rivalries—and inequities—beyond Earth's boundaries?

Replicating the wild west on the moon, where the first person to arrive claims the land, is not an option in the 21st century. Humans will all be "terrestrials" when they land on the moon, regardless of national flags.

Space can be a platform for diplomacy as well as conflict. It can also be a tool for socio-economic development. These are powerful incentives for humankind to act as partners on the final frontier.

Expanding humanity's footprint beyond Earth is the biggest challenge of this century and beyond. So a global effort to explore outer space collaboratively and peacefully is not only possible, but mandatory.

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LVM3-M5/CMS-03 Mission

26 October 2025

Source: ISRO | https://www.isro.gov.in/LVM3_M5_CMS_03_MISSION.html

LVM3-M5/CMS-03 MISSION

India’s LVM3 launch vehicle is scheduled to launch the CMS-03 communication satellite in its 5th operational flight (LVM3-M5) on November 02, 2025. CMS-03 is a multi-band communication satellite that will provide services over a wide oceanic region including the Indian landmass. CMS-03, weighing about 4400kg, will be the heaviest communication satellite to be launched to Geosynchronous Transfer Orbit (GTO) from Indian soil. The previous mission of LVM3 launched the Chandrayaan-3 mission, where in, India became the first country to land successfully near the lunar south pole.

The launch vehicle has been fully assembled and integrated with the spacecraft and has been moved to the Launch Pad on October 26, 2025 for further pre-launch operations.

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Aerospace Industry

350km Range Astra Mk3 'Gandiva' BVR Missile Set for 2028 Production Clearance; IAF Induction Planned by Early 2030

Raghav Patel | 24 October 2025

Source: Defemnce.in | https://defence.in/threads/350km-range-astra-mk3-gandiva-bvr-missile-set-for-2028-production-clearance-iaf-induction-planned-by-early-2030.15866/#google_vignette

India is moving steadily toward a major enhancement of its air combat capabilities with the Astra Mk3, a next-generation air-to-air missile.

According to new reports, the indigenous missile is projected to complete its development trials and receive clearance for production by 2028, with plans for induction into the Indian Air Force (IAF) by the early 2030s.

This advanced weapon, also known as 'Gandiva', is a beyond-visual-range (BVR) missile designed by the Defence Research and Development Organisation (DRDO).

It is engineered to strike hostile aerial targets at an exceptional distance of up to 350 kilometres, placing India in a select group of nations with such long-range aerial technology.

The key to the Astra Mk3's remarkable range is its advanced propulsion system, a Solid-Fuel Ducted Ramjet (SFDR).

Unlike conventional solid-propellant rockets, which burn out quickly, an SFDR is an air-breathing engine. It ingests atmospheric oxygen for combustion, which significantly reduces the need to carry a heavy oxidizer.

This allows the missile to fly further, sustain high supersonic speeds (reportedly up to Mach 4.5), and maintain energy for manoeuvres during the final phase of its attack.

This extended reach is a strategic game-changer, enabling the IAF to neutralize high-value assets like enemy AWACS (Airborne Warning and Control Systems) and mid-air refuelling tankers from a safe standoff distance.

By targeting these "force multipliers," a small number of missiles can effectively cripple an adversary's ability to coordinate a large-scale air operation.

For its guidance, the Astra Mk3 will be equipped with a state-of-the-art indigenous Gallium Nitride (GaN) based AESA (Active Electronically Scanned Array) seeker.

This advanced "brain" of the missile is highly resistant to electronic jamming and provides superior targeting. This system, combined with mid-course updates via data-link, allows a fighter pilot to launch the missile and turn away, a capability known as "lock-on-after-launch" (LOAL).

The missile, which weighs approximately 220 kilograms and measures 4 meters in length, is progressing through its development.

Following successful ground-based validation of its propulsion and seeker systems, the DRDO is reportedly preparing for live-fire trials. These trials, expected to begin in late 2025, will involve launching the missile from frontline fighters such as the Su-30MKI and the future Tejas Mk2.

Once the trials are complete and production clearance is granted in 2028, mass production will be handled by the state-owned enterprise Bharat Dynamics Limited (BDL).

The Astra Mk3 is the pinnacle of India's indigenous air-to-air missile programme, which aims to achieve self-reliance in critical defence technologies.

It completes a tiered family of weapons, which includes the operational Astra Mk1 (110 km range) and the in-development Astra Mk2 (around 200 km range), ensuring the IAF can cover all ranges of BVR combat.

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GTRE Acquires Advanced Load Cell Calibration System for Small Thrust Engine Testing

21 October 2025

Source: Indian Defence News | https://www.indiandefensenews.in/2025/10/gtre-acquires-advanced-load-cell.html?m=1

The Gas Turbine Research Establishment (GTRE), under India's Defence Research and Development Organisation (DRDO), is procuring an advanced load cell calibration system to enhance the precision of thrust measurement in its Small Thrust class engine program.

This acquisition represents a key step in advancing India's indigenous aero-engine testing infrastructure, ensuring that thrust readings during static test firings attain the highest degree of accuracy and repeatability.

Load cell calibration systems are critical for verifying and standardising the measurement of engine thrust, which directly influences performance evaluation, design validation, and certification.

The system enables precise calibration of sensors used in thrust stands, eliminating deviations in measurement caused by temperature, vibration, or electronic drift.

Such accuracy is especially essential for small thrust engines, which require high sensitivity and fine measurement resolution due to their lower power output range.

This procurement underscores GTRE's ongoing efforts to expand and modernise its engine testing ecosystem. The calibrated data obtained will support various thrust chamber validation tests and performance mapping activities vital for projects such as indigenous air-breathing propulsion systems, UAV engines, and micro gas turbines. With this development, GTRE moves closer to achieving internationally benchmarked standards in static engine test reliability and data accuracy.

Technical Specifications and Operational Details of GTRE Load Cell Calibration System

Parameter	Description
System Purpose	Calibration of load cells used in measuring thrust output during static engine fire tests.
Applicable Engine Class	Small Thrust class engine (typically below 5 kN thrust range).
Calibration Type	Dead weight-based or hydraulic load calibration system ensuring traceability to national standards.
Measurement Range	Configurable up to ±5,000 N with high-resolution output for low-thrust precision testing.
Accuracy Level	Better than ±0.05% of full-scale output, ensuring minimal deviation in test data.
Load Resolution	1 N or finer, suitable for micro-level thrust measurement in small engines.
Operational Mode	Automated with real-time data acquisition and control via digital interface.
Calibration Frequency	Adjustable load application sequence from 10% to 100% of rated capacity.
Data Interface	Ethernet/USB-based integration with GTRE's test stand control console.
Temperature Compensation	Built-in temperature correction matrix to maintain accuracy across 0°C-50°C range.
Safety Features	Overload protection up to 150% of rated capacity with automatic load release mechanism.
Certification and Traceability	Complies with ISO/IEC 17025 calibration standards; traceable to NABL-accredited calibration reference.
Software Integration	Compatible with GTRE thrust stand software modules for real-time calibration data logging and analysis.
Maintenance Cycle	Annual recalibration and verification by in-house quality metrology laboratory.
Expected Service Life	Designed for 10-12 years of continuous laboratory use with periodic recalibration intervals.

Integration of Load Cell Calibration System Into GTRE's Thrust Measurement Setup

The newly acquired load cell calibration system will be integrated into GTRE's existing thrust measurement infrastructure, primarily used for static testing of small thrust engines.

The system will serve as a precision reference unit to verify and calibrate the primary load cells installed on static thrust stands before and after each engine test series.

During integration, the calibration rig will be mechanically aligned with the thrust stand's load-bearing frame to ensure accurate force transmission between the calibration actuator and the load cell assembly.

The system's data acquisition unit will be linked to GTRE's digital control console through a high-speed Ethernet interface, enabling real-time load application, monitoring, and linearity checks. The interfaced software will record calibration curves, correct non-linearities, and automatically adjust thrust measurement factors to compensate for system drift or mechanical deflection.

This integration ensures that each testing cycle produces traceable and repeatable thrust data, critical for evaluating combustion efficiency, nozzle alignment, and pressure ratio performance across various operating regimes. It also strengthens GTRE's internal validation framework, ensuring all thrust measurements align with ISO and NABL calibration standards, thereby improving the reliability of indigenous engine development efforts.

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India Accelerates 800-km BrahMos Missile Tests with Modified Ramjet Engine and Hybrid Navigation, Readiness Expected by 2027

Raghav Patel | 22 October 2025

Source: Defence.in | https://defence.in/threads/india-accelerates-800-km-brahmos-missile-tests-with-modified-ramjet-engine-and-hybrid-navigation-readiness-expected-by-2027.15861/

Rajnath Singh & Moroccan trade minister Ryad Mezzour in Rabat

India is significantly enhancing its military capabilities by fast-tracking the development of an 800-kilometer-range BrahMos supersonic cruise missile.

This powerful conventional weapon, produced by the BrahMos Aerospace joint venture between India's DRDO and Russia, is undergoing critical tests on a modified ramjet engine.

According to defence sources, the goal is to have this new precision-strike system fully operational and ready for combat by the end of 2027, reinforcing India's strategic posture.

According to a high-level defence official, the primary engineering work on the missile's new ramjet engine is largely complete

The current phase of testing focuses on its advanced navigation system. This hybrid system combines an internal Inertial Navigation System (INS) with external satellite guidance (like GPS or India's own NavIC).

These final tests are essential to confirm the missile's pinpoint accuracy and its ability to resist electronic jamming by adversaries.

The missile's original range was restricted to 290 kilometers. This was to comply with the rules of the Missile Technology Control Regime (MTCR), an international agreement to prevent the spread of long-range missile technology.

After India formally joined the MTCR in 2016, it was no longer bound by this limit, leading to an upgraded 450-500 km variant in 2017.

A key strength of the BrahMos is its versatility, as it can be fired from land-based mobile launchers, naval ships, and Sukhoi-30MKI fighter jets.

This upgrade to 800 kilometers represents more than a simple range extension; it is a major technological overhaul designed to secure India's long-term deterrent capabilities.

The central innovation is the re-engineered ramjet engine. A ramjet is an air-breathing engine that uses the missile's own high speed to compress air for combustion. This design allows it to maintain powerful, sustained thrust over much greater distances while preserving its high speed and agility.

Ensuring the missile's accuracy over this new, longer distance is a primary focus of the current trials.

The hybrid navigation system (INS-GNSS) is critical; the INS provides constant guidance independent of external signals, making it resistant to jamming, while satellite updates correct its path to achieve "sub-meter" (less than one meter) accuracy.

This counters electronic warfare tactics, such as GPS jamming. Recent trials, including a flight in early 2025 that reportedly used a new domestically-developed seeker, have shown promising results.

A key advantage of the new 800-km variant is its design for easy integration into existing platforms.

For the Indian Navy, which already operates the BrahMos on approximately 20 warships, the upgrade is expected to be straightforward. It will primarily involve software and fire-control system updates, allowing the new missile to be operational just months after receiving final approval.

The Indian Army's land-based units will also be upgraded, while the Air Force variant may need a slightly longer timeline for additional flight testing.

This extended-range missile comes at a critical time for India's national security, given the heightened border tensions with China and persistent threats from Pakistan.

A longer-range weapon allows for "standoff operations," where high-value targets can be struck precisely from a safe distance, minimizing risk to pilots and troops.

The BrahMos, with its powerful conventional warhead designed to destroy hardened targets, will work alongside other systems like the tactical Pralay ballistic missile and the 1,000-km range Nirbhay subsonic cruise missile.

Together, these weapons could form the core of a new, proposed Integrated Rocket Force.

Strategic analysts describe the 800-km BrahMos as a significant development. It provides India the ability to threaten key military assets deep inside enemy territory without crossing borders, acting as a powerful deterrent.

Because it carries a conventional (non-nuclear) warhead, its use aligns with India's "no-first-use" nuclear policy. This enhancement also boosts the missile's export prospects, building on the existing sale to the Philippines and interest from other nations.

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AI will Make Drone Threats a Nightmare – it could also save us

Paul Lemmo | 29 October 2025

Source: Breaking Defense | https://breakingdefense.com/2025/09/ai-will-make-drone-threats-a-nightmare-it-could-also-save-us/

Image courtesy of Lockheed Martin

Imagine you're standing watch on a military base's security forces team, monitoring for potential air threats. Your radar screen is cluttered with tracks – commercial aircraft, flocks of birds, and civilian and commercial drones. You see what looks like a small aircraft veering towards your fence line.

Is that a threat? A delivery drone flying off course? A hobbyist drone operator snapping a picture of a sunset? Or is it an AI-trained distraction while the real threat masks its approach from another direction?

Drones already present a formidable challenge for military and homeland security forces. AI-guided drones could be a nightmare, using advanced tactics to hide their movements or coordinate swarming attacks custom-designed to overwhelm defenses.

The good news? AI is uniquely suited to powering exceptional drone defenses. Here's how:

Learning algorithms are excellent at spotting and tracking drones: In a noisy or cluttered radar environment, drones could slip through cracks in sensor detection. But AI can be trained specifically to separate signal from noise in a given environment.

An AI-powered system can become an expert in the area around a military base, for example, learning the local landscape, structures, and even weather patterns so it knows how to pick out and track drone anomalies with exceptional accuracy.

AI can match defensive weapons to drone targets much faster than humans: Once the drone is spotted, a counter-UAS system has to know how to best determine intent and to plan for mitigation. But that depends on many complex factors. Is the drone carrying explosives? Is it vulnerable to a cyber or electronic attack? Could a laser take it down safely?

For operators in a command center, making those decisions from a dozen or so football fields away can cost precious minutes. But an AI algorithm can be trained to recognize and evaluate different drone threats in an instant, evaluating its weaknesses and capabilities to quickly find and recommend the best way to maintain safety and sovereignty. It can also be trained on policy and rules of engagement to know which responses best align to regulations, assisting operators in a complex data rich environment.

AI might be the only way to move fast enough to repel a drone swarm: In a large swarm scenario, human operators can be quickly overwhelmed. A well-trained AI system, governed by robust safety protocols, could take over defenses, rapidly prioritizing and engaging drones to stave off a powerful assault. Such a defense would require layering offensive and defensive tactics, a feat only an AI-powered system could likely pull off.

Building an Intelligent Counter-UAS Network

Sanctum™, Lockheed Martin's Counter-UAS system, is proving out those AI-driven capabilities in joint exercises worldwide. From precision tracking and targeting to real-world takedowns of drone threats, Sanctum is demonstrating the power of smart, layered defense.

Sanctum is customized for each deployment, using a combination of layered defensive systems and a core AI mission management system that is trained to detect drones in cluttered environments, track them with confidence, and identify the level of threat they pose. The system then recommends the ideal weapon-target pairing to take them out quickly and safely.

Sanctum's AI is a learning algorithm. What Sanctum sees in one location trains the system everywhere. When Sanctum tracks a new threat or recognizes a different UAS behavior, it shares those updates across the network. That makes each node smarter, and helps keep Sanctum-equipped defenses ahead of the threat.

That software is built on the same Lockheed Martin-designed air and missile defense technology like the Aegis Combat System that's countering drone and cruise missile threats in places like the Red Sea. From sensors and sensor fusion to automated weapon-target pairing and precision intercepts, these technologies are battle-tested, not just beta-tested.

We combine that AI mission management brain with a mix of the top-performing sensors and effectors from across the commercial and defense tech industry. Sanctum's open architecture means there's no vendor lock and no requirement to use Lockheed Martin tech. Each defensive network is built for what the mission needs, from software to sensors to shooters. And as new innovations come online, Sanctum can integrate new tech with ease.

The result is a system that's custom-designed and diligently trained to defend each unique location. That delivers more effective security, with better chances of seeing and stopping drones in their tracks without risking the safety of a base or the surrounding area.

Sanctum gives operators a decisive edge over a rapidly evolving drone threat.

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DRDO Successfully Conducts Maiden Flight of Indigenous Archer-NG MALE UAV

24 October 2025

Source: Indian Defense News | https://www.indiandefensenews.in/2025/10/drdo-successfully-conducts-maiden.html?m=1

The Defence Research and Development Organisation (DRDO), through its Aeronautical Development Establishment (ADE), has successfully conducted the maiden flight of the indigenous Archer-NG Medium Altitude Long Endurance (MALE) UAV.

This significant milestone marks a crucial phase in India's drone development program, reflecting years of dedicated research and testing to bolster the country's aerial capabilities.

The Archer-NG is a single-engine, twin-boom configured UAV designed to deliver advanced intelligence, surveillance, reconnaissance, and strike capabilities. Weighing around 1,800 kg with a payload capacity of up to 400 kg, the aircraft is built to undertake long-duration missions, with an endurance of approximately 24 to 29 hours and a service ceiling near 30,000 feet.

Such endurance allows persistent monitoring over vast areas for the Indian Armed Forces, fulfilling critical operational requirements.

This UAV features a modular design

accommodating diverse payloads, including electro-optical/infrared (EO/IR) sensors, synthetic aperture radar (SAR), electronic warfare systems, and air-to-ground precision munitions such as laser-guided bombs and missiles.

The Archer-NG's weaponisation capabilities are intended to be combat-ready within the next few years, further enhancing its multi-role operational profile

Prior to its first flight, the Archer-NG completed extensive ground evaluations, including low-speed and high-speed taxi trials, which validated the aircraft’s structural integrity, landing gear, braking systems, and engine performance under simulated take-off and landing conditions.

Its propulsion is provided by an indigenously developed 177-horsepower turbocharged engine that brings important benefits in operational autonomy and supply chain security, paving the way for self-reliant defence technologies.

Designed to incorporate advanced avionics and a comprehensive ground control system consistent with prior UAV programs like TAPAS, the Archer-NG embodies India’s commitment to develop world-class indigenous unmanned aerial platforms capable of network-centric operations and seamless interoperability with manned assets.

The maiden flight of Archer-NG not only represents an achievement in India’s growing aerospace and defence industrial base but also significantly strengthens the country’s tactical and strategic capabilities in surveillance and combat roles. With further tests and weaponisation development underway, the Archer-NG is poised to become a key asset for the Indian Armed Forces in the near future.

Concise technical specification sheet for the Archer-NG MALE UAV:

Parameter	Specification
Type	Medium Altitude Long Endurance (MALE) Unmanned Aerial Vehicle (UAV)
Configuration	Single-engine, twin-boom pusher type
Manufacturer	DRDO in collaboration with HAL (India)
Maximum Takeoff Weight (MTOW)	Approximately 1,700 kg
Payload Capacity	Up to 400 kg, modular multi-payload system
Endurance	24-29 hours (enhanced from earlier 12-hour TAPAS version)
Service Ceiling	Approximately 30,000 ft
Operational Altitude	Up to 22,000 ft (earlier Archer) with improvement in Archer-NG
Range	Around 220 km (Line-of-Sight)
Engine Type	Indigenous 177 hp turbocharged engine
Propulsion Layout	Rear-mounted pusher propeller
Avionics Suite	Advanced avionics with autonomous take-off and landing system
Ground Control Compatibility	Compatible with DRDO’s TAPAS Ground Control Station (GCS) and Ground Data Terminal (GDT)
Hardpoints	Four hardpoints for armament integration
Weapon Payloads	Laser-guided bombs, Smart Anti-Airfield Weapons (SAAW), Anti-Tank Guided Missiles (ATGMs), loitering munitions, and future Astra Mk1 BVRAAM integration
Sensor Payloads	EO/IR sensor suite, Synthetic Aperture Radar (SAR), Electronic Warfare (EW) suite, optional AESA radar for advanced surveillance and fire control
Mission Roles	Intelligence, Surveillance, Target Acquisition, Reconnaissance (ISTAR), precision strike missions, artillery target acquisition, post-strike assessment, multi-role combat operations
Weaponisation Status	Fully weaponised variant expected within three years of maiden flight
Special Features	AESA radar integration planned for multi-target tracking and air-to-air capability
Primary Users (Projected)	Indian Air Force, Indian Navy, and Indian Army

These specifications underscore the Archer-NG's role as a versatile and potent indigenous UAV platform capable of performing long-endurance reconnaissance missions and precision combat strikes, enhancing India’s operational autonomy and aerial warfare capability.

> **"Theater air power is primarily a denial instrument, usually used together with land power. Inasmuch as these instruments are not used punitively, studying them cannot help discern the relative effectiveness of different coercive strategies."**
>
> **- Robert A. Pape**

The Centre for Aerospace Power and Strategic Studies (CAPSS) is an independent, non-profit think tank that undertakes and promotes policy-related research, study and discussion on defence and military issues, trends and developments in air power and space for civil and military purposes, as also related issues of national security. The Centre is headed by Air Vice Marshal Anil Golani (Retd).

Centre for Aerospace Power and Strategic Studies
P-284 Arjan Path, Subroto Park, New Delhi - 110010
Tel.: +91 - 11 - 25699131/32 Fax: +91 - 11 - 25682533
Email: capsnetdroff@gmail.com
Website: https://capssindia.org/

Advisor : AVM Ashish Vohra VSM (Retd)
Editor, Concept & Content : Ms Gowri R

Composed by Mr Rohit Singh
Tel.: +91 9716511091
Email: rohit_singh.1990@hotmail.com