

# **Report on 16<sup>th</sup> 'Jumbo' Majumdar International Seminar**

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## **'EVOLVING DYNAMICS OF AEROSPACE POWER'**

### **INAUGURAL SESSION**

The 16th 'Jumbo' Majumdar International Seminar was organised by the Centre for Air Power Studies (CAPS) on March 04, 2025, at the Air Force Auditorium, Subroto Park, New Delhi. The seminar explored the theme "Evolving Aerodynamics of Aerospace Power". The seminar brought together key personnel from the Indian Air Force (IAF), Ministry of Defence (MoD), industry representatives, academia, scholars, aviation enthusiasts and think tanks to discuss the changing contours of aerospace power in future conflicts and the impact of transformative technologies on aerospace power.

#### **Welcome Remarks**

##### **Air Vice Marshal Anil Golani (Retd.) Director General, CAPS**

The session started with the opening remarks from Air Vice Marshal Anil Golani, Director General, CAPS, who highlighted the growing aerospace challenges for India due to the unprecedented rise of unmanned systems, emerging aerospace technologies, exponential growth in the exploitation of space and cyberspace domains and the weaponisation of trade, technology, and information warfare amid a near breakdown/transition of the global order.

He also highlighted his concerns at the shifting air power balance with our northern adversary (China), which has inducted the fifth generation aircraft (J-20) into The People's Liberation Army Air Force (PLAAF) in large numbers. It also caught the world by surprise by showcasing its rapidly growing military aviation capabilities with the first flight of its sixth-generation fighter prototype over the skies of Chengdu on December 26, 2024. The proposed induction of the fifth generation aircraft by our western adversary (Pakistan) also is a cause of concern. The key question for India

is how to address/bridge this growing capability gap—whether to procure the F-35 or the Su-57 or accelerate the development and induction of the indigenous Tejas Mk II (four and a half generation) and Advanced Medium Combat Aircraft (AMCA) (fifth generation) programmes—something the recently constituted Defence Secretary-led MoD committee would look into.

Thereafter, he introduced the theme and session for the seminar, highlighting the significance of Indo-EU strategic ties and urging India to leverage new opportunities in defence and space collaboration.

Before concluding, he paid his tributes to Wg Cdr Krishna Kumar 'Jumbo' Majumdar a daredevil pilot, war hero, and IAF icon.

### **Book Releases**

#### **Air Chief Marshal A.P. Singh PVSM AVSM, Chief of the Air Staff, IAF**

The inaugural session concluded with the simultaneous release of three books written by CAPS scholars (a coveted first time for CAPS) by the Chief of the Air Staff, Air Chief Marshal A.P. Singh. The titles and the abstracts of the books that were released are as follows.

The first book that was released, **“IRAN: A Misjudged, Misunderstood, Misconstrued Nation”**, was written by **Air Marshal Dhiraj Kukreja AVSM VSM (Retd.)**. The book comprehensively analyses Iran’s historical, political, and socio-economic landscape, focusing on its evolution from ancient times to the present day. It delves into the significant events that have shaped Iran, including the 1979 Islamic Revolution, which replaced the Shah’s pro-Western monarchy with a theocratic republic led by Ayatollah Khomeini.

The second book that was released, **“India’s Pursuit in Hypersonic Flight”**, was written by **Air Marshal GS Bedi AVSM VM (G) VSM (Retd.)**. The book takes readers on a thrilling journey through the evolution of high-speed motion to future breakthroughs. It explains complex hypersonic technology to both experts and aviation enthusiasts having no prior knowledge of the subject in simple everyday language without the usage of complex terminologies or formulas.

The third book that was released, **“Energy Cooperation Between India and the Caspian Region”**, was written by **Dr Ngangom Dhruba Tara Singh**, Associate Fellow at CAPS. The book primarily focuses on energy cooperation between India and the Caspian Sea region, which includes

the countries of Azerbaijan, Russia, Kazakhstan, Turkmenistan and Iran, which garner global attention because of their hydrocarbon reserves and transit capability. Amidst the ongoing conflict in Ukraine, this book offers a timely contribution to pertinent energy cooperation issues by examining the complex dynamics of energy security and geopolitical interests.

## **SESSION I**

### **AEROSPACE POWER IN FUTURE CONFLICTS**

**Chair: Air Chief Marshal VR Chaudhari PVSM AVSM VM (Retd.),  
Former Chief of the Air Staff**

The session was chaired by the former Chief of the Air Staff, Air Chief Marshal VR Chaudhari PVSM AVSM VM (Retd.). He highlighted the significant evolution in airspace management due to the rapid technological advancements. He underlined that traditional methods of managing airspace, which involved lengthy closures during spacecraft launches, have become impractical due to the increasing number and frequency of space launches and the ever-increasing complexity and congestion of modern air traffic.

He stressed the need for automation and the integration of advanced technologies, such as artificial intelligence (AI), which is crucial for effectively managing airspace, especially with the proliferation of advanced air mobility services and the challenges posed in the airspace over the battlefield due to the ever-increasing and diverse users of the air domain.

The Chair highlighted three aspects of airspace management at present. Firstly, spacecraft controls, which focuses on managing airspace during spacecraft launches and re-entries, has been characterised by the evolution from lengthy airspace closures to much shorter closures due to technological advancements and better space situational awareness (SSA). Secondly, advanced air mobility services, which encompasses emerging air services such as air taxis, are expected to congest the low-altitude airspace in urban areas. The management of this airspace, especially with the integration of a wide variety of unmanned aerial vehicles and low-flying helicopters, presents significant challenges. Thirdly is battlefield airspace management, which deals with the complexities of managing airspace in combat situations, where various platforms (like unmanned aerial vehicles (UAVs)), loitering munitions, fighter aircraft, attack helicopters, cruise missiles and artillery)

compete for airspace, making effective management crucial. Therefore, the Chair called for a reduction in the separation and a shift from tactical to strategic management of the aerospace domain.

**Gp Capt (Dr) DK Pandey (Retd.), Senior Fellow CAPS on ‘Integrated Aerospace Management: The Way Forward for the IAF’**

Gp Capt DK Pandey highlighted the evolving complexities in aerospace domain management due to the increasing diversity of users and systems. He underlined that a fragmented approach not only results in inefficiency but can also be exploited by adversaries for their advantage. Therefore, he named integrated aerospace management (IAM) as the need of the hour and a way forward for the IAF. As a strategic approach, IAM focuses on the fusion of data from all the available sensors for efficient, effective and coordinated use of air and space power.

He highlighted that IAM can drastically improve the situational awareness (SA) and facilitate decision making, thereby enhancing India’s space deterrence and resilience and survivability of space-based assets.

The speaker also presented the case study of the Joint All-Domain Command and Control (JADC2) initiative of the United States Air Force (USAF). The JADC2 aims to establish a fully networked unified command structure.

In his recommendations for the IAF, he brought out the urgent need for a robust and secure data network and communication architecture. He called upon IAF to work towards enhancing domain awareness through the development and integration of ground-based and airborne multi-sensor fusion system, AI-enabled decision making, which shortens the observe, orient, decide and act (OODA) loop and facilitates command and control and secures large-scale data management. He called for investment in high-bandwidth, low-latency, and cyber-resilient communication networks capable of supporting massive data transfers across all domains and the implementation of multi-layered cybersecurity strategies to protect these interconnected systems. He also emphasised the need for joint and coalition interoperability standards and protocols. He also suggested the development of common data standards and SOPs with the sister services to enable seamless data sharing, joint ops planning, and coordinated responses. He underlined the importance of adaptive training and education curriculum

for encompassing data analytics, AI appreciation, cyber awareness, multi-domain operations and joint interoperability.

He also suggested certain emerging technologies and their application into the realm of IAM, as brought out below:

Sl. No.	Technology	Application
1.	AI/ML	Multi-sensor fusion Automated C2 Threat assessment Decision support
2.	Quantum computing and sensing	Data processing
3.	Hypersonics threat and directed energy weapons	IAM security
4.	Autonomous systems and swarm tech	Coordination of dynamic operations
5.	Advanced sensors (passive and active)	To provide data in fusion engines
6.	Secure and resilient communication networks (5G/6G, satellite, quantum-resistant encryption)	Robust and secure communication.
7.	Data analytics and visualisation tools	Understanding the complex aerospace picture

He concluded by emphasising that the IAM is not merely desirable but a strategic imperative for the IAF in the way going ahead.

### **Gp Capt Rahul Basoya VM (G) Gp Capt (Plg and Impl), Defence Space Agency on Effective Space Exploitation for gaining ‘Control of the Air’**

Gp Capt Rahul Basoya’s presentation on effective space exploitation for gaining control of the air highlighted the ever-increasing importance of the space domain in modern warfare. He emphasised how recent conflicts, such as those between Russia-Ukraine and Israel-Hamas, have demonstrated the strategic role of satellites in intelligence gathering, navigation, and communication. The space-based services are huge enablers and essential for achieving success in operations in all domains.

One of the main lessons has been the significant impact of satellite imagery—like that offered by commercial enterprises like Maxar on military decision-making. Military strategy has changed drastically as a result of the ability to continuously track troop movements, identify enemy positions, and evaluate battlefield conditions in real-time. Similarly, navigation systems have been used both offensively and defensively in all domains, with enemy

operations being disrupted through the jamming and spoofing of global positioning system (GPS) or other satellite-based navigation systems.

The speaker argued that because space-based assets offer vital services like intelligence, surveillance, and reconnaissance (ISR), position, navigation, and timing (PNT), and satellite communication (SatCom), they are essential for achieving and preserving air superiority and air supremacy. Modern air operations would be severely constrained in the absence of these space based services.

Speaking about India's capabilities, the speaker highlighted that although advancements have been made in India's space capabilities in ISR, navigation, and communication satellites, much more needs to be done to make these facilities available in real-time and catch up with the capabilities of our Northern adversary in space. He cited programmes like Mission DefSpace, which aims to improve domestic space capabilities by working with the private sector. In order to leverage the commercial advancements in space-based technologies for national security, he underlined the need to enhance civil-military integration.

One of the presentation's main conclusions was that air control is only feasible if space assets are available, functional and secure. The speaker emphasised that India must improve the defence space agency capabilities and fortify its space-based infrastructure in order to retain the strategic edge. Utilising real-world examples such as the US drone strike on Iranian General Qasem Soleimani, which was coordinated through satellite communication, the speaker also emphasised the significance of combining space, air, and cyber capabilities into a coherent defence strategy.

The speaker advocated the urgent need to develop hybrid space architecture capabilities, software defined satellites, defence cloud capability with the use of satellites in medium earth orbit (MEO), and space based military internet of things that he called M-IoT. By doing these, India would be able to guarantee continuous access to space-based services, which are considered essential for gaining advantage in operations across domains.

### **Wg Cdr A Pichipoo Raja, Research Fellow, CAPS on Exploitation of Drones, Manned Unmanned Teams (MUMT) in Future Conflicts**

Wing Commander A. Pichipoo Raja's presentation on drones and manned-unmanned teaming (MUM-T) in future conflicts highlighted

the transformative impact of drones on modern warfare. He structured his discussion around three key elements: hardware, ideas, and people, emphasising that while technology is a force multiplier, human expertise remains the deciding factor in war.

By overcoming earlier restrictions in environments like dense forests, cities, and underground facilities where conventional air assets had trouble navigating, drones have increased the reach of air power. He provided examples of how sustained operations without reliance on intricate military-industrial supply chains have been made possible by inexpensive, readily assembled drones, such as containerised drone factories. This innovative change has improved the accessibility, mobility, and sustainability of airpower, especially in lengthy, protracted conflicts.

The speaker also propounded the guerrilla air warfare (GUAVA) theory, which applies the concepts of guerrilla warfare to drone operations. According to this model, drones are effective in asymmetric warfare because they prioritise mobility, psychological impact, self-sufficiency, and local support. Additionally, he examined their function in peer-to-peer conflicts, where the maintenance of air dominance requires MUM-T tactics that combine physical, cyber, and spectrum superiority in contested airspaces.

He concluded that drones do not replace human skills, tactical innovations, or doctrinal adaptations, even though they have transformed aerial warfare by bringing airpower to previously inaccessible areas. The speaker cautioned against the illusion of capability, which could result from the overconfidence of simple drone technology. In addition to cutting-edge equipment, future warfare would require skilled soldiers who should be able to quickly adapt and counter new threats.

## **SESSION II**

### **TRANSFORMATIVE TECHNOLOGIES IN AEROSPACE POWER**

**Chair: Air Vice Marshal Ashish Vohra VSM (Retd.) Additional Director General, CAPS**

The Chair of the second session, Air Vice Marshal Ashish Vohra, opened the discussion by highlighting the profound impact of transformative technologies on aerospace power. He underlined how technological

developments have changed air warfare, impacting the conduct and character of conflict and its strategic ramifications. As evidenced by the recent wars in Ukraine, Israel, and Azerbaijan-Armenia, the swift development of disruptive technologies has brought about an unprecedented change in airpower.

The democratisation of airpower was a significant theme in his remarks. With the advent of low-cost UAVs, smaller countries and even non-state actors now have access to advanced military capabilities that were previously only accessible by major powers. Traditional kinetic weapons have given way to non-kinetic alternatives like electronic warfare, cyber warfare, information warfare, and directed energy weapons because of the shift from industrial-age warfare to information-age warfare and, more recently, automation-age warfare. The distinction between combatants and civilians has become blurred due to these technologies, increasing the complexity and unpredictability of modern warfare.

The Chair emphasised the growing importance of cyber warfare, characterising it as transformative and disruptive. He noted that, as was the case in Russia-Ukraine conflict, where Russian forces took down important communication networks just hours before the ground invasion, future wars would probably start with a contestation, competition or a conflict in the cyberspace domain. He cautioned that a multi-domain digital battlefield would be created as state and non-state actors increasingly target vital infrastructure, such as financial systems, military command-and-control networks, and power grids.

According to the Chair, attribution—identifying the party responsible for the cyber attack—is one of the most difficult aspects of cyber warfare. Having ascertained the accountability/responsibility for the cyber-attack, deciding on an appropriate response is an even more problematic geopolitical task. The Chair highlighted the huge dilemma of whether cyber-attacks qualify as acts of war and, if so, whether nations should respond with a kinetic attack or a cyber counterattack. The Chair also emphasised that the effectiveness of electronic warfare (EW) gets accentuated if integrated with a cyber attack. These conundrums would shape future international policies and military doctrines. His remarks set the stage for the session's discussion.

### **Air Cmde VV Gupta VM PD OPS (IEW), Air HQ (VB) on Offensive and Defensive Cyber and EW Operations**

Air Cmde VV Gupta began his presentation by highlighting the increasing significance of EW and cyber in contemporary military operations. He emphasised how cyber capabilities have impacted everything from command-and-control networks to weapon systems, becoming essential for every facet of multi-domain warfare. Cyber warfare is now more than just a support role due to the quick digitisation of military operations; it is a key component in attaining tactical, operational, and strategic advantages.

He framed his discussions around the potential impact of cyber-attacks on aerospace operations, illustrating how offensive cyber operations can disrupt, degrade, or even take control of military assets. He pointed out that modern aircraft, such as the F-35 fighter jet, rely highly on interconnected digital systems, making them vulnerable to cyber intrusions. Furthermore, recent events involving military and civilian aircraft have shown how cyber warfare techniques like GPS spoofing and electronic jamming can confuse or interfere with navigation and targeting systems.

The speaker also cautioned about the risks associated with open-source intelligence (OSINT), which allows adversaries to obtain sensitive military information merely by looking at publicly accessible data and social media posts. Through several examples, the speaker emphasised the need for all military personnel and their family members to be cyber vigilant and avoid making simple mistakes of putting digital media posts regarding their station activities, which could lead to leakage of sensitive tactical information.

He concluded his presentation by emphasising that cyber operations are critical but must coexist with traditional combat strategies. Since cyber and EW operations would be crucial in determining the results of future conflicts, he reiterated the need to incorporate them into all military plans.

### **Wg Cdr Achu Kuzhiyeth, Directing Staff, CAW on Exploitation of Emerging and Niche Technologies by the IAF**

The second speaker for the session was Wg Cdr Achu Kuzhiyeth. His presentation focused on how new and emerging technologies are already impacting aerial warfare, which would further increase in the future. He highlighted how these technologies—AI, additive manufacturing or 3D

printing, quantum technology, quantum communications, and directed energy weapons (DEWs)—would impact future aerial warfare. He gave examples of how these technologies are already changing military tactics worldwide, such as Australia’s development of unmanned loyal wingman drones, the United States deployment of laser weapon systems, and China’s breakthroughs in quantum communications.

He highlighted that AI would be essential for cyber defence, target identification, intelligence collection, and autonomous decision-making, especially in swarm drones and MUM-T operations. In a similar vein, 3D printing is transforming military logistics by facilitating the quick manufacture of weapon components, UAVs, and spare parts—a method already applied in Ukraine’s drone conflict. The potential of quantum technology to improve encryption and sensing while making conventional cybersecurity measures outdated presents both opportunities and risks. A 2 kilowatt laser weapon for counter-drone warfare was recently demonstrated by India, demonstrating how DEWs are becoming a revolutionary defence mechanism against drones, missiles, and aerial threats.

The speaker underlined the necessity of public-private partnerships, enhancing indigenous research and development, and strategic alliances to speed up the development of these vital technologies if the IAF is to remain competitive. He pointed out that China leads in most critical technologies, while India is among the top five in 45, highlighting the need for closer industrial and diplomatic ties with developed nations. He also emphasised the need to enhance the defence research and development funding, both in public sector and private sector companies, if India is to catch up with the developed nations in critical technologies. He also emphasised programmes like the National Quantum Mission (2023) and Indo-US technology partnerships to achieve technological self-reliance.

As the way forward, he laid down certain imperatives in terms of actions that India and the IAF need to pursue. He insisted on the development of dual-use technology and an increase in the overall budget for research and development along with accountability. He brought out the need to broaden defence reforms and develop a long-term strategy considering the aerospace Power’s sensitivity to technology. He alluded to the need for the development of cutting-edge technologies vs resigning to the loop of capability-product-customer. He brought out the need for domain-specific

research and development. As the way forward, he underlined the need for joint structures and technology development cycles. He propounded the need to enhance the scope for the Directorate of Aerospace Design (DAD), Innovations for Defence Excellence (iDEX) and Technology Development Fund (TDF), along with cross-engagements with the industry and the academia.

In conclusion, he emphasised that niche and emerging technologies would shape aerial warfare in the future and that India must take a whole-nation approach with enhanced research and development funding, regulatory assistance, and active military involvement in defence innovation to guarantee India's technological advantage in the changing battlefield.

**Gp Capt Girish Dantale VSM, Station Commander, AF Stn Utterlai on Fifth and Sixth Generation Fighters in our Neighbourhood: Way Forward for the IAF**

Gp Capt Girish Dantale VSM was the third and final speaker of the session. In his presentation, he focused on the technological advancements, the technological challenges, and the future capabilities of fifth and sixth-generation fighter aircraft. He highlighted how these aircraft represent the cutting edge of emerging and niche technologies discussed earlier in the session. These technologies include multi-spectral low observability (stealth), multi-sensor data fusion providing enhanced SA, supercruise capabilities, super-maneuvrability due to thrust-vectoring, adaptive sixth generation engines, an impressive array of air-to-air and air-to-ground precision long-range weapons and MUM-T as loyal wingmen. He compared the development timelines of advanced fighter jets by the Americans and the Chinese with their fifth generation aircraft, such as the F-22, F-35, J-20, and J-35, pointing out that China has significantly reduced its aircraft development cycles. The speaker cited the example wherein China carried out the demonstration flight of its first sixth generation fighter prototype (J-36) a bare four years after the demonstration flight of the American sixth generation fighter prototype (Next Generation Air Dominance). He emphasised that a large extent of this has been possible through espionage and reverse engineering and, to a certain extent, by the enhanced research and development funding by China.

The restrictions on the number of missiles that stealth aircraft can carry due to their internal weapons bays were a significant source of concern. He

pointed out that fighters such as the F-35 and J-20 are adjusting by adding more external hardpoints, even if it means sacrificing stealth. Although the J-20's WS-15 and other powerful engines indicate a move towards supercruise capability, obvious design flaws like protruding nozzles and large canards make it difficult to achieve all-aspect stealth. Furthermore, incorporating AI and sensor fusion into next-generation fighters poses software challenges because even minor changes necessitate intricate system-wide upgrades, which could result in vulnerabilities.

The speaker also covered the operational and logistical challenges of maintaining these expensive aircraft. Significant obstacles include battle damage recovery, high maintenance costs due to the frequent repairs to the surface material and stealth coatings, and cyber vulnerabilities because even minor damage to stealth coatings can reduce the aircraft's effectiveness. In order to support sophisticated manufacturing technologies, like electron beam melting and laser additive techniques for lightweight engine components, he emphasised the necessity of advanced field-level repair capabilities and industry readiness.

He suggested a mix of aircraft of different generations for the IAF, with advanced aircraft handling high-value targets and four and a half generation fighters assisting with operational requirements. He underlined the significance of investing in domestic multi-spectral radar systems, increasing cyber resilience, speeding up AMCA development, and increasing aerial refuelling capabilities. In conclusion, he emphasised the need for a national strategy that integrates industry, the military, and the government to attain self-reliance in next-generation aerospace technologies.

### **The Question and Answer Session**

In the question and answer session, the topic of India's fifth and sixth-generation aircraft development and the relative importance of weaponry, speed, and stealth were discussed. Experts stressed that next-generation fighters need to have an integrated strategy that balances several technologies instead of concentrating on a single capability. The conversation also brought up India's need for closer military, academic, and industrial cooperation, especially in cutting-edge areas like 3D printing and quantum communication. Serving officers' ignorance of ongoing research

and technological developments was one of the main issues brought up, highlighting the necessity of organised interaction of the service officers with the academia and the industry representatives from the various technology hubs.

On the transition to sixth-gen aircraft, panellists debated whether India should attempt to leapfrog directly into sixth-gen capabilities to catch up with our Northern adversary or first master fifth-generation technologies. The consensus was that developing AMCA is crucial for gaining expertise in stealth, avionics, and fifth generation high-powered stealthy engines before attempting the development of sixth generation technologies. Cyber vulnerabilities, sustainment challenges, and interoperability were identified as key hurdles. The discussion also touched on stealth detection through space-based surveillance and multi-spectral radars, though limitations in real-time tracking ensure that stealth still remains relevant. The session concluded with a strong call for better national integration of research and development efforts to keep pace with the rapidly evolving aerial warfare technologies.

### **Closing Remarks**

**Air Vice Marshal Anil Golani (Retd.), Director General, CAPS**

The seminar concluded with the closing remarks from Air Vice Marshal Anil Golani. He concluded the event by highlighting key takeaways from the day's proceedings. He acknowledged the significant contribution of various experts and emphasised the importance of continued collaboration in aerospace. While addressing the question raised regarding collaboration with academia, he underlined that the Directorate of Aerospace Design, established at Air Headquarters, is actively engaging with IITs and universities to explore technological advancements and collaborative opportunities.

One significant recommendation from him was that the government and private defence organisations need to create a venture capital fund. It would only take a few successful case studies to show that this initiative has the potential to propel defence-related technological advancements, unlike iDEX grants. AVM Anil Golani concluded by thanking the entire organising team for their efforts in making the event a success.

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## **Action Points**

### **16<sup>th</sup> ‘Jumbo’ Majumdar International Seminar**

**March 04, 2025**

**Integrated Aerospace Management (IAM):** Recent wars in Ukraine and Israel have tellingly brought out once again that “Control of the Air”, both over land or sea, is a critical war-fighting necessity. The IAF’s Integrated Air Command and Control System (IACCS) must be upgraded to an aerospace command and control system, wherein apart from the management of the Indian airspace over both land and sea, the IAF must also have the ability to manage the near space and space as well. The concept of integrated air domain awareness should be expanded to integrated aerospace domain awareness and must facilitate IAM. Towards this, the IAF must invest in emerging technologies like quantum computing, hypersonic missile defence, and secure communication networks.

**Enhancing the Capabilities of the Defence Space Agency (DSA):** The indigenous intelligence, surveillance and reconnaissance (ISR), positioning, navigation and timing (PNT), and satellite communication capabilities need to be enhanced expeditiously so that the DSA can provide situational awareness and real-time mission support to operations in all domains, i.e. on land, sea, air and cyberspace. Additionally, the space-based infrastructure needs to be fortified to improve its resilience, security and operational effectiveness. To guarantee continuous and unrestricted access to space-based services during conflicts, there is an urgent need to develop space domain awareness (SDA) and hybrid space architecture capabilities, which should include space-based military internet of things (IoT) and defence cloud capabilities. Simultaneously, there is an urgent need for greater civil-military integration so as to ensure that commercial advancements in space-based technologies can be leveraged by the military as well.

**Enhanced Utilisation of Drones and MUM-T in Future Wars:** Unmanned aerial vehicles, loitering munitions, and first person view (FPV) drones have had a transformative impact on recent wars. These have enhanced the transparency of the battlefield and increased the lethality and reach of air power, especially in the difficult and restricted environments of dense forests, urban built-up areas, and even underground facilities. The indigenous military-industrial complex must be expanded and strengthened so as to

be able to mass-produce inexpensive yet precise and potent drones for the specific battlefield requirements of the three Services. Defence Research and Development Organisation (DRDO) and private sector companies need to focus on expeditiously developing and producing personal air defence systems (PADS) and the technologies for MUM-T so as to enable the attainment of air superiority in contested airspaces and striking strategic enemy targets in depth with minimum risk to manned flights. All three Services need to invest in the training and skill enhancement of their personnel to effectively exploit the transformative capabilities of drones and MUM-T.

**Strengthening Cyber and EW Capabilities of the IAF:** Success in cyber and EW operations would be essential for achieving victory in all future conflicts. Therefore, both offensive and defensive cyber and EW operations need to be an integral part of all the tactical, operational and strategic missions during integrated multi-domain operations. With the ever-increasing digitisation and the networking of the battlefield in all domains, cyber warfare would only become even more disruptive and all-pervasive in future conflicts. Therefore, IAF and the other Services need to ensure multi-layered security of their networks through strong encryption, strong and updated firewalls, intrusion protection systems, regular cyber-security training and efficient cyber-security practices by their personnel. Families of service personnel also need to be educated on cyber hygiene to prevent unintentional leakages through OSINT. India must also formulate detailed cyber response policies laying down responsibilities and actions, both during peacetime and during war.

**Exploitation of Niche and Emerging Technologies by the IAF:** Niche and emerging technologies have revolutionised air power and made it much more lethal, potent and precise. Presently, India is a distant third in the indigenous development of most of the emerging technologies, i.e. after China and the US. India needs to catch up with them through increased defence research and development funding, not only for the defence public sector units (DPSUs) but also for the private defence industry. The MoD must do the requisite hand-holding of the defence start-ups and the defence micro, small and medium enterprises (MSMEs). India must adopt a 'whole-of-nation' approach with the DRDO, academia, think tanks, defence industry and the Services working together to develop some of these critical emerging technologies. India must leverage its strategic autonomy and

its strategic alliances with the developed nations for technology transfers, co-development, and co-production of certain technologies to leapfrog and achieve self-reliance in the aerospace domain. IAF must also focus on developing laser weapons for counter unmanned aerial systems (CUAS), quantum communications for securing networks and 3D printing for building defence infrastructures.

**Indigenous Development of the Fifth and Sixth Generation Aircraft:**

The fifth and sixth generation aircraft represent the pinnacle of aviation technology and manifest niche aviation technologies like multi-spectral low observability or stealth, multi-sensor data-fusion, supercruise and super manoeuvrability capabilities, adaptive engines, and MUM-T. In order to cut down the capability gap with our adversaries, India needs to expeditiously increase the production rates of the indigenous four and a half generation aircraft like the Tejas MkIA and MkII, enhance their indigenous content, and diversify the supply chains of their critical components. Simultaneously, India needs to speed up our fifth generation aircraft, AMCA's development and also do the necessary tie-up for the indigenous co-development and co-production of a high-thrust jet engine with (intellectual property) IP rights with an established international engine original equipment manufacturer (OEM). India also needs to formulate a national aerospace strategy that facilitates synergistic and focused development of critical aviation technologies and military aviation platforms through the collaborative efforts of the indigenous aviation industry, defence start-ups, academia, think tanks, the military, and the MoD so as to attain self-reliance in the aerospace domain.