AIR POWER

Journal of Air Power and Space Studies

Vol. 17 No. 4 • Winter 2022
(October-December)

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IS INDIA READY TO CONQUER UNMANNED AERIAL WARFARE?

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UNMANNED AERIAL VEHICLES

In 1917, the world's first modern Unmanned Aerial Vehicle (UAV) was developed, possessing the potential to fundamentally change the future of warfare. Eighty-four years later, the Predator drone fired a Hellfire missile, signalling the UAV's arrival as an armed unmanned flying vehicle[1] and today, UAVs comprise major determining tools in combat. One hundred and eighty-six drone strikes were launched in Yemen, Syria, and Pakistan by the US during Obama's first two years, whereas the tally reached 238 during Trump's first year and 11 months in office.[2] Today, the global market for UAVs is around $21.47 billion and the Indian market is estimated to be worth $866 million.[3] Some countries have established significant UAV development projects with the help of their aviation manufacturing industry,

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1. Chris Cole, "Rise of the Reapers: A Brief History of Drones", https;//dronewars.net/2014/10/06/rise-of-the-reapers-a-brief-history-of-drones/. Accessed on December 15, 2021.
2. News Desk, China, "Hamas & More: US Not Alone, A List of Countries That've Aced Drone Warfare", *News18*, August 28, 2021, https://www.news18.com/news/world/from-china-to-hamas-not-just-us-heres-list-of-countries-thatve-aced-drone-warfare-4136906.html. Accessed on December 10, 2021.
3. Manish Tewari, "India Needs to Gear up Battle in World of Drones", *Deccan Chronicle*, January 2, 2022, https://www.deccanchronicle.com/opinion/columnists/010122/manish-tewari-india-needs-to-gear-up-for-battle-in-world-of-drones.html. Accessed on January 5, 2022.

UAVs are not restricted by human limitations, such as the need for life support equipment or G-tolerance, which gives them the potential to eventually be superior to manned aircraft. Against the increasing costs of hardware, advanced armour and modern targeting systems, UAVs present an affordable alternative.

while others have been importing them for incorporation into their security forces.

Manned vs Unmanned Aerial Vehicles

UAVs are becoming increasingly prevalent as they can be deployed in large numbers at a very low price. If small UAVs are employed smartly, it may become difficult to trace their origin and find out their launch base. Individuals can operate them to get a quick view of the battlefield, enabling them to see where the enemy is, without being at risk themselves. UAVs are not restricted by human limitations, such as the need for life support equipment or G-tolerance, which gives them the potential to eventually be superior to manned aircraft. Against the increasing costs of hardware, advanced armour and modern targeting systems, UAVs present an affordable alternative. Their key feature is the ability to provide real-time information on what the enemy is up to, its location, and activities. These drones are real threats to large and expensive air defence systems and, when combined with Artificial Intelligence (AI), they will not even need an operator. Hence, they possess the potential to replace the existing manned aircraft to a great extent.

Drone Technology: A Double-Edged Sword

In October 2020, the Azerbaijani troops exploited Israeli kamikaze drones extensively against the Armenian soldiers in the Nagorno Karabakh conflict with spectacular results, while hundreds of Syrian armoured vehicles were destroyed by the Bayraktar TB-2 combat drones used by the Turkish forces one year later. Interestingly, unlike stealth hypersonic, and other advanced weapons, UAVs are not limited to the superpowers with massive defence budgets. They are well within the budget of any country

or even a non-state actor. Previously, any ability to conduct precision strikes required millions of dollars' worth of guided systems incorporated on aircraft or huge expensive cruise missiles, but not any more, as several hundred of these $200 drones can easily be procured from a local store, a small warhead strapped on them and then launched to attack and destroy a very expensive aircraft or radar.

A UAV's low price, easy accessibility, simple functioning and non-requirement of professional or long-term training are some of the reasons of its misuse by non-state actors. India encountered its first UAV attack on June 27, 2021.

Drones are also being used to carry out confined and largely autonomous terrorist strikes, posing a serious new security concern. Yemen's Houthi rebels carried out drone attacks on Saudi Arabian oil facilities in 2019 and the fuel tank of the oil giant Abu Dhabi National Oil Company (ADNOC) of the United Arab Emirates (UAE) on January 17, 2022. A UAV's low price, easy accessibility, simple functioning and non-requirement of professional or long-term training are some of the reasons of its misuse by non-state actors. India encountered its first UAV attack on June 27, 2021. Two low-flying drones carrying Improvised Explosive Devices (IEDs) targeted the Air Force Station, Jammu; one exploded on a rooftop and did slight damage, while the other exploded in an open area. Two Indian Air Force (IAF) personnel were injured, and two more drones were spotted the next day over the Kaluchak Military Station in Jammu. This deliberate armed attack, keeping in mind India's two hostile neighbours, was a wake-up call for India which raised concerns among national security strategists.[4] Therefore, this paper will deliberate on the following questions:

- Why does India need to strengthen its unmanned aerial warfare capability?
- What is India's present unmanned aerial capability gap between that and the required strength?

4. Bushra Tungekar, "Are Drones a Threat to National Security? Are the Drone Laws in India Strong Enough?", *iPleaders*, July 28, 2021, https://blog.ipleaders.in/are-drones-a-threat-to-national-security-are-the-drone-laws-in-india-strong-enough/. Accessed on December 13, 2021.

- How can UAVs be integrated in the Indian air space, its major challenges and solutions?
- What are some of the counter-drone mechanisms being used by India to defend its air space against unmanned offensives?
- What are the challenges that India's aviation ecosystem faces that directly influence its unmanned aerial capabilities?
- What is the recommended strategy to prepare for, and triumph in, in this new-age unmanned warfare?

INDIA'S NEED TO STRENGTHEN ITS UNMANNED AERIAL WARFARE

India's need to strengthen its unmanned warfare capabilities essentially originates from the threat posed by internal and external agents to its national security. Since the beginning of 2019, there have been over 300 drone sightings across the country, some of them in the Naxal, Maoist and Left-Wing Extremism (LWE) affected states, and mostly in the border areas. China and Pakistan, the two hostile neighbours of India, are both well-equipped with unmanned technology, posing a grave threat to the national security. In September 2019, drones were used to airdrop weapons, ammunition, fake currencies, communication devices, etc. in Punjab from across the border. One year later, a drone carrying a rifle, two magazines, and a stockpile of grenades was shot down by the Border Security Force (BSF).[5] During the Galvan clash in 2020, Chinese drone activity was quite visible in the friction points like the Daulat Beg Oldie sector and Gogra heights. A year after that, when India welcomed diplomats from several countries to mark 75 years of its independence, a drone hovered above the premises of the Indian High Commission in Islamabad (Pakistan) which could not have happened without the tacit support of state actors in Pakistan.

These incidents led to the speeding up of the strengthening of India's unmanned aerial warfare capabilities. The fact of the matter remains that the drone threat is not new, even in India. Indian Army Chief General M M

5. Tewari, n. 3.

Naravane in July 2021, asserted that this technology will play a decisive role in the future of warfare where conflicts could potentially have drastically lower number of losses of life, both military and civilian. Identifying the adversary's potential plays a vital role in determining the level to which India's capacity will have to be built.

NATURE OF INDIA'S HOSTILE NEIGHBOURHOOD

China's Unmanned Capabilities

The opening ceremony of the Air Show China, 2021 drew international attention, with several of China's advanced drones making their debuts, such as the GJ-11 Sharp Sword stealth UAV, WZ-7 and WZ-8 reconnaissance UAVs[6] and twin tail Scorpion-A large, three-engine UAV. China's UAVs with ISR (Intelligence, Surveillance, and Reconnaissance) and strike capabilities are likely to pose new threats to its neighbours, particularly those with whom it has border disagreements, like India. It reflects China's faith in its world class UAV technology, which is the outcome of a collaborative effort between its public and private sectors.

China's People's Liberation Army Navy (PLAN) employs a variety of UAVs, including the BZK-005 (naval variant), WZ-009 High Altitude Long Endurance (HALE), and ASN- 209 Medium Altitude Long Endurance (MALE) (Kania E). The PLAAF (PLA Army Air Force) also uses a variety of UAVs for reconnaissance, including the BZK-005, WZ-009, and CH-802.[7] According to Stockholm Peace Research Institute (SIPRI), China has delivered 220 drones to 16 countries during the last decade.[8] Although Chinese drones do not match the best products from American and Israeli

6. GT staff reporters in Zhuhai, "China's Most Advanced Stealth Drones Make Air Show Debut", *Global Times,* September 28, 2022, https://www.globaltimes.cn/page/202109/1235398.shtml. Accessed on January 18, 2022.
7. Nihar Kulkarni, "China and UAVs", *Fins India,* October 12, 2021, https://finsindia.org/china-and-uavs/. Accessed January 20, 2022.
8. Bruce Einhorn, "Combat Drones Made in China Are Coming to a Conflict Near You", *Bloomberg Businessweek,* March 17, 2021, https://www.bloomberg.com/news/articles/2021-03-17/china-s-combat-drones-push-could-spark-a-global-arms-race. Accessed on January 20, 2022.

Since the late 1990s, Pakistan has made substantial investments in UAVs and possesses a mix of indigenously produced and externally acquired small and tactical drones.

companies, they are becoming competitive, are less expensive than those supplied by the United States or Israel, and China is least concerned about how and where they are employed. DJI, a Chinese company, is dominating the civilian UAV market not just in India but on a global level. The Chinese public sector company Aviation Industry Corp of China (AVIC) is aiming to become the world leader in military UAVs, having sold military drones worth more than $22 billion.[9]

PAKISTAN'S DRONE ARSENAL

Since the late 1990s, Pakistan has made substantial investments in UAVs and possesses a mix of indigenously produced and externally acquired small and tactical drones. The deployment of the US MQ-1 Predator MALE armed UAVs in the country gave it first-hand experience of the capabilities of armed drones. It was so impressed by this, that it attempted to purchase them; however, this did not work out, therefore it resorted to licensed manufacture of the Chinese CH-3A armed tactical UAV, which was named Burraq.[10] It deployed the Burraq in an anti-insurgency mission in 2015.

Pakistan possesses a fleet of imported top-of-the-line UAVs such as the SELEX Galileo from Italy and the CH-4 from China. In 2021, the Pakistan Air Force (PAF) received an undefined number of Wing Loong IIs and inked a co-production agreement with Turkey for the ANKA armed MALE UAV. The Pakistan Navy followed the army's lead and chose the CH-4B,

9. Jamie Whitney, "Combat Drones in China are Coming to a Conflict Near You", *Military Aerospace*, March 19, 2021, https://www.militaryaerospace.com/commercial-aerospace/article/14232081/china-military-drones-uav-unmanned. Accessed on January 20, 2022.
10. Farooq Bhai in collaboration with Stijn Mitzer, "Thunder From The East-Pakistan's Operational UAV Fleet", *Oryx*, January 5, 2022, https://www.oryxspioenkop.com/2022/01/thunder-from-east-pakistans-operational.html. Accessed on February 1, 2022.

unclassified numbers of which were supposedly delivered in late 2021.[11] All of these events raise concerns in India.

In order to protect the national interest of India against its internal and external threats, the requirement of the forces need to be identified, current capabilities analysed and the gap between them bridged effectively.

GAP BETWEEN THE REQUIREMENT AND PRESENT CAPABILITY

India's Indigenous UAV Development Programme

India is a latecomer to UAV development, with most of its indigenous UAVs in the development or certification stages. The development of UAVs in India began in the 1980s with the Defence Research and Development Organisation's (DRDO's) production of the Pilotless Target Aircraft (PTA). But, this development has not progressed at the desired speed due to lack of competitive and high-quality aircraft production facilities, as well as reliance on imports for crucial technologies such as semi-conductors, electronics, and engines.

ACCOMPLISHMENT OF PUBLIC SECTOR

Indian Research and Development (R&D) firms have made some headway in designing and producing UAVs; nevertheless, these UAVs are still in the early stages of development. The National Disaster Management Authorities (NDMAs), central and state government departments, Central Armed Police Forces (CAPFs) and civil industry have employed indigenously designed mini-UAVs. While India created the PTA, micro and mini-UAVs, its MALE UAV and UCAV (Unmanned Combat Aerial Vehicle) still remain in the certification and development stage respectively.

The Golden Hawk, Black Kite, and Pushpak Micro Aerial Vehicles (MAVs), as well as the Indian Eagle and Sly Bird mini-UAVs, have been developed by the National Aeronautics Laboratory (NAL) but the fact that

11. UASUCAVs", *Oryx*, September 5, 2021, https://www.oryxspioenkop.com/2021/09/lifting-veil-pakistans-chinese-ucavs.html. Accessed on February 7, 2022.

none of these could enter service is an indication of the lack of synergy between the development agency and users. The first mini-UAV developed by DRDO in partnership with a start-up was the Netra quadcopter, while the Nishant was one of DRDO's first tactical UAV projects. Owing to the concerns that Nishant's vehicle launch might give away its location to satellites, a wheeled version, the Panchi, was created. But the production of the Nishant was discontinued due to the initial challenges and subsequent lack of orders, while the induction of the Panchi was cancelled.

The indigenous MALE UAV development programme of the DRDO reached a milestone in March 2022 with the Rustom-II crossing an altitude of 27,500 ft with 18 hours endurance.[12] It is expected to be technologically comparable to, and less expensive than, the current imported UAVs, according to officials. It has been developed by the Aeronautical Development Establishment (ADE) in Bengaluru, with Hindustan Aeronautics Ltd (HAL) as the production partner.

PRIVATE SECTOR'S CONTRIBUTION TO CAPACITY BUILDING

The private sector's involvement in UAV design and development has been confined to a few start-ups; however, many new players are entering the UAV manufacturing industry. IdeaForge Technology, India's largest small drone producer for defence, homeland security, and industrial applications was one of the few private companies to enter the UAV development field as early as in 2007. It created the SWITCH UAV, which it described as a "first-of-its-kind" Vertical Take-Off and Landing (VTOL) and fixed-wing hybrid UAV. The army awarded IdeaForge a $20 million (about Rs 148 crore) contract in January 2021 for an unspecified number of advanced SWITCH tactical drones. These customised devices

12. Raunak Kunde, Indian Defence Research Wing, News Beat, March 14, 2022, https://idrw.org/rustom-ii-uav-demonstrates-28000-feet-and-18-endurance-moves-closer-to-target/#:~:text=In%20December%202021%2C%20Rustom%2D%20II,requirements%20set%20by%20the%20Services. Accessed on March 30, 2022.

are designed for usage by the infantry and special forces in high-altitude terrain like Ladakh. Another UAV firm, Vinveli, has two variants of its flagship Vero drone, which is built in India. Their transporting capability is not just limited to bombs, but also extends to food delivery to soldiers on the battlefield.

RESPONSIBILITIES, CAPACITIES AND DEMANDS OF THE ARMED FORCES

Army

The Indian Army's demand for UAVs originates from its area of responsibilities such as protecting the large Indian land border, which includes high altitude hills, deserts, plains, and thickly forested hilly terrain. In 1996, the Indian Army purchased the Searcher Mark-I UAVs, which were followed by the Searcher Mark-II[13] and Heron UAVs from Israel for Intelligence, Surveillance, Reconnaissance (ISR) tasks.[14] There are around 90 Herons in total with the tri-Service. One major flaw with the Herons now in service with India is that they are not integrated with satellite navigation, which would improve range and coverage. Following tensions with China along the Line of Actual Control (LAC) since May 2020, the army has leased four of the latest generation of Herons, dubbed the Heron II.[15] It has also been providing anti-aircraft fire training to its air defence crew with the PTA, which may need to be improved in the future to handle rising air

13. Major General PK Chakraborty, "Unmanned Aerial Vehicles (UAVs): Indian Perspective", February 2012, http://www.indiastrategic.in/topstories1369_Unmanned_Aerial_Vehicle.htm. Accessed on January 15, 2022.
14. Manu Pubby, "India Loses its Troop Scanning Heron UAV, Secretive Sensors to China Crash", December 7, 2017, https://theprint.in/report/india-loses-its-troop-scanning-heron-uav-sensors-to-crash/20932/. Accessed on January 15, 2022.
15. Raghav Bikhchandani, "Heron, Searcher, Sea Guardian, SWITCH: The Many UAVs that Make up India's Drone Arsenal", *The Print*, August 6, 2021, https://theprint.in/defence/heron-searcher-sea-guardian-switch-the-many-uavs-that-make-up-indias-drone-arsenal/709670/. Accessed on February 3, 2022.

During anti-terrorist operations, the Indian Army requires nano or micro-UAVs for locating terrorists holed up in buildings or confined places, and mini-UAVs for conducting surveillance in the areas of field formations.

threats from enemies.[16] During anti-terrorist operations, the Indian Army requires nano or micro-UAVs for locating terrorists holed up in buildings or confined places, and mini-UAVs for conducting surveillance in the areas of field formations.

The army's infantry battalions deploy a variety of quadcopters, which are deployed by the soldiers for tactical surveillance on the border and patrols during anti-terrorism operations to gain a better understanding of the situation. These low cost, small drones are widely employed by the military along the Line of Control (LoC) and in Jammu and Kashmir (J&K). MALE/HALE UAVs, on the other hand, are expensive, restricted in number, and necessitate specialist staff, massive infrastructure, and extensive support systems. For long-term surveillance and as radio relays to extend communication range, drones that are tethered could be deployed.

Air Force

The IAF's demand for UAVs stems from its area of responsibility, the capability of its adversaries, and the envisaged operational missions. This mandates that India's MALE and HALE UAVs be able to operate at high altitudes and have extended ranges in order to conduct ISR missions across the country's extensive borders and varied terrains. To facilitate Beyond Visual Line of Sight (BVLOS) missions in hilly terrain, they also need satellite control.

To engage in the active combat role, UAVs in the IAF need capabilities, sensors, and armament to engage in enemy territory in a dense air defence situation. Smaller UAVs would also be required for monitoring of its air bases as well as surveillance missions during special operations. The IAF

16. "Request for Information (RFI) for Procurement of Basic Pilotless Target Aircraft (BPTA)", April 15, 2015, https://indianarmy.nic.in/MakeInIndia/Site/FormTemplate/tendorsView.aspx?MnId=/mSkto7YE9IIPCvHB0nlwA==. Accessed on January 15, 2022.

employs two types of kamikaze drones, the Harpy and the improved Harops, both of which were purchased from Israel. The Harpy is an all-weather, day-and-night 'fire and forget' autonomous weapon system that is primarily employed to disable enemy radars and, hence, performs DEAD (Destruction of Enemy Air Defence) and SEAD (Suppression of Enemy Air Defence) missions.[17] Whereas, the Harop is a Loitering Missile (LM) that can be used to take out a variety of targets, including moving vehicles. It is an electro-optically guided attack weapon.

In order to increase surveillance efforts across the Indian Ocean Region (IOR), the Indian Navy deploys the Heron and Searcher Mk II drones and leased two Sea Guardian drones in 2020. The Indian Navy requires mini-UAVs for combat and amphibious ships to conduct special/ assault operations-and-anti-piracy in offshore or coastal regions.

Navy

In order to increase surveillance efforts across the Indian Ocean Region (IOR), the Indian Navy deploys the Heron and Searcher Mk II drones and leased two Sea Guardian drones in 2020. The Indian Navy requires mini-UAVs for combat and amphibious ships to conduct special/assault operations-and-anti-piracy in offshore or coastal regions. For operations from smaller ships, the rotary wings, quadcopters, and rail-launched tactical UAVs are required. It needs MALE and HALE UAVs for ISR, communication relay operations, and other combat missions. In addition, it needs 'fire and forget' loitering, launched from tube/rail for SEAD or DEAD to neutralise enemy command and control installations, radar stations, surface-to-air missiles, and other targets. Also, target drones are needed for target acquisition and aircraft fire training for the ships' air defence crews.

CAPFs

For anti-Naxal operations, the CAPFs need UAVs with sensors that can conduct surveillance over areas with dense vegetation, in fog, or in

17. Bikhchandani, n. 15.

terrible weather. Once these capabilities are established, the CAPFs are likely to possess UAVs in greater numbers. Micro and mini-UAVs are needed for surveillance, policing, anti-Naxal operations, maintaining law and order, and other purposes. The CAPFs also require tactical UAVs for border patrolling.

ONGOING DEVELOPMENTS

UAVs with long endurance are a top priority for the military, especially for the eastern Ladakh region in view of the stalemate with China. The Heron UAVs of the Services are undergoing an upgrade with Israel's help under Project Cheetah that includes arming them.[18] India was also exploring the feasibility of purchasing 30 MQ-9 Reaper or Predator B drones from the United States under the tri-Service initiative;[19] however, it has not shown any progress.

While bridging the gap between the required UAV capabilities and present capacity of India, integration of the same must be done parallelly to further strengthen the unmanned aerial ecosystem of the country.

INTEGRATION OF UAVS IN THE INDIAN AIR SPACE

Integration of UAVs in the existing common air space is not only important to ensure the safe operation of UAVs alongside manned aircraft in a dynamic air environment, but also to detect hostile surveillance and protect friendly UAVs from exploitation by adversaries. The major security concern among the aviation regulators is regarding the sensitivity of UAV command-and-control signals and communication systems, which can be misused for subversive purposes. Therefore, it becomes necessary to formulate a technological solution and create a legal framework for distinct monitoring. Various measures are being taken to overcome the challenges for seamless

18. Dinakar Peri, "Rustom-2 Indigenous UAV Crosses a Milestone", *The Hindu*, December 15, 2021, https://www.thehindu.com/news/national/rustom-2-indigenous-uav-crosses-a-milestone/article37963891.ece
19. Bikhchandani, n. 15.

integration of UAVs into the established Air Traffic Control (ATC) protocols[20] to safeguard India's interest against internal and external threats.

Technological Challenges

A UAV requires secure data and voice connectivity links to provide a command-and-control link between the UAV and its operator/pilot in the ground control station for controlling the UAV's operation. It is also required to share videos and data from other sensors with the ground control station and other aircraft. It facilitates smooth establishment of radio telephony (voice) contact between the UAV operator and air traffic control for de-confliction of a UAV's operation with other aircraft. Due to the unpredictability of the link and the weakening of signals, the command-and-control link between the pilot and the UAV could experience disruptions ranging anywhere from just a few seconds to a few minutes. When a data link is lost, control is lost for a period of time, posing a security risk as the adversaries can take advantage of it. UAVs operating close to, or within, enemy territory are vulnerable to hostile jamming, interference, and hacking.

Drone-to-drone combat or a drone face-off is a significant constituent of drone warfare, where identification and elimination of a hostile drone play a vital role. To enable UAVs to execute autonomous actions for traffic de-congestion and collision avoidance, aerial and ground-based sensors and surveillance equipment like Sense and Avoid (SAA) and Traffic Alert and Collision Avoidance System (TCAS) are required. The SAA detects clashing traffic, predicts its trajectory, analyses this data to determine the likelihood of a collision, and takes autonomous corrective actions to avoid it.[21] The designers of the SAA system confront obstacles such as designing compact, lightweight, and minimal battery consuming sensors, as well as simpler and

20. "Characteristics of Unmanned Aircraft Systems and Spectrum Requirements to Support their Safe Operation in Non-Segregated Airspace", Report ITU-RM.2171 (12/2009), International Telecommunication Union, https://www.int/en/ITU-R/space/snl/Documents/R-REP-M.2171-2009-PDF-E.pdf. Accessed on March 5, 2022.
21. "FAA Faces Significant Barriers to Safely Integrate Unmanned Aircraft Systems into National Airspace System", https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Unmanned%20Aircraft%20Systems%5E6-26-14.pdf. Accessed on January 30, 2022.

The US Army designed a Ground Based Sense and Avoid System (GBSAA) to provide distinction between UAVs and other traffic, with its controller directing UAV pilots to avoid potential conflict areas while simultaneously warning ATC controllers.

efficient algorithms for speedier computing, and smaller storage boards for installation on small UAVs. These systems must also be tough enough to function in a variety of settings and weather situations.

The TCAS is an aerial system that compares velocity and direction to offer warning about the time to go for a collision. It works on the secondary radar principle and needs the other aircraft to have a transponder. It determines the collision location by assuming that both aircraft will continue to fly straight, with no changes in heading. This is a major shortcoming of this technology. The lower accuracy of the position and rate of change of the vertical position in the TCAS, as well as the time lag caused by the operation of a UAV via remote control, also poses a collision risk.[22]

Technological Solutions

The US Army designed a Ground Based Sense and Avoid System (GBSAA) to provide distinction between UAVs and other traffic, with its controller directing UAV pilots to avoid potential conflict areas while simultaneously warning ATC controllers. It is made up of the Lightweight Surveillance and Target Acquisition Radar (LSTAR) System, which can identify and track different aircraft, including tiny and slow-moving UAVs and helicopters. This system was also being tested by the US Navy and Marine Corps.[23] However, this seemed to be a short-range detecting system, and its accuracy in distinguishing between small, slow-moving UAVs and birds could not be determined.

22. Tiwari, n. 3.
23. Thomas P. Spriesterbach, Kelly A. Bruns, Lauren I, Baron, and Jason E. Sohlke, "Unmanned Aircraft System Airspace Integration in the National Airspace Using a Ground-Based Sense and Avoid System", http://www.jhuapl.edu/techdigest/TD/td3203/32_03-spriesterbach.pdf. Accessed on January 31, 2022.

The National Aeronautics and Space Administration (NASA) presented the cloud-based monitoring system with software tools for traffic monitoring and traffic separation in November 2015. It made use of a combination of the Automatic Dependent Surveillance-Broadcast (ADS-B) gear, ground radars and geo-fencing software based on the Global Positioning System (GPS).[24] Similarly, the European Aviation Safety Agency (EASA) launched the Drone Awareness and Monitoring System (DAMS). The DAA (Detect and Avoid System), ALIAS (Aircrew Labour In-Cockpit Automation System), and MIDCAS (Mid-Air Collision Avoidance System) are some more solutions that are being developed to address this technological challenge and Indian drone manufacturers can certainly draw inspiration from them to develop Indian versions.

To incorporate UAVs in the non-segregated air space and keep a record of all the compliant UAVs, operating crews must be licensed, UAVs must be certified, and data communications must be legally secured.

Legal and Regulatory Challenges

Air space regulators are responsible for ensuring that piloted aircraft and people on the ground are not endangered and to safeguard them from unmanned aerial attacks, they must create or alter rules, regulations, and other policies. To incorporate UAVs in the non-segregated air space and keep a record of all the compliant UAVs, operating crews must be licensed, UAVs must be certified, and data communications must be legally secured. By simply handing over the radio control frequency to another operator hundreds of miles away, a UAV or Remotely Piloted Aircraft (RPA) can be commanded from multiple locations. Hence, the regulations would have to contain legal measures for apportioning duty when many crew members are in charge of the UAVs. The security of the Ground Control

24. Sharon Lozano, "First Steps Toward Drone Traffic Management", November 20, 2015, https://www.nasa.gov/feature/ames/first-steps-toward-drone-traffic-management. Accessed on January 30, 2022.

System (GCS) would have to be a criterion for granting clearances for UAV operations, according to the regulations. This will help in reducing the chances of the UAV control getting into the wrong hands. And also keep a track of the pilots as well as UAVs flying at any given point of time in a particular air space.

Drone Regulations in India

The Drone Rules, 2021, were promulgated by the Central Government of India on August 25, 2021 following the principles of "trust, self-certification, and non-intrusive monitoring" while lowering the scope of regulatory control. The prior rules' stringent requirements such as certificate of conformity, certificate of maintenance, operator permissions, import clearance, R&D authorisation, and so on, were repealed, and the red tape involved in obtaining compliance was minimised.

All persons owning or possessing, or engaging in leasing, operating, transferring, or maintaining a drone in India, as well as all drones registered in India or currently being operated in or over India, are covered by the rules.[25] These aim to restrict solely civilian drone use and do not apply to drones deployed by the Indian Navy, Army or Air Force.[26] To operate a drone, the rules necessitate obtaining a type certificate from the director general or any organisation permitted by him. Manufacturing or importing a UAV, as well as operating a model or a nano UAV, do not require a type certificate.[27] In addition to drone certification, the rules require individual drone registration on the platform and the acquisition of a Unique Identification Number (UIN).[28]

The central government has divided India's air space into three zones: red, yellow, and green.[29] The rules also provide a self-reporting process, requiring that any drone-related mishap be reported to the Director General

25. Rule 2(1).
26. Rule 2(3).
27. Rule 13.
28. Rule 14(1).
29. Rule 19.

Civil Aviation (DGCA) through the Digital Sky Platform within 48 hours.[30] The rules specifically prohibit operators not having a valid Remote Pilot Licence (RPL) to operate micro and above categories of drones.[31] The rules are a one-of-a-kind amalgamation of regulation and liberalisation in Indian law. These regulations will help in monitoring all the drones being flown and differentiate between a registered and an illegal drone. The degree to which this experiment of law in India with self-regulation and non-intrusive inspection succeeds will, however, be determined by proper air space mapping with regular updates and platform usability, which will be the government's responsibility.[32]

The integration of UAVs into the Indian air space is an important activity not only to monitor, detect and minimise the potential UAV threat but also to defend the air space against a drone attack by neutralising it, which requires development and deployment of counter-drone technology.

COUNTER-UNMANNED AERIAL SYSTEMS

Many countries have failed to protect themselves against small drone strikes despite having an elaborate Air Defence (AD) network. Conventional AD systems like the Patriot and S-400 have been designed to tackle the threat posed by large, fast-moving flying machines and are not effective against small, slow and low flying drones. Small drones are difficult to detect and neutralise because of their size, extensive usage of carbon composites and plastics, low radar footprint, and low sound levels of electric motors.[33] Other more effective options of short and medium range AD systems such as the Pantzir and Avenger are still expensive and could quickly run out of missiles and ammunition as was noted back in 2017, when

30. Rule 30.
31. Rule 31.
32. Kunal Verma and Sai Anukaran, "India: The Drone Rules, 2021: An Unmanned Flight Into Unchartered Territory", *Mondaq*, September 3, 2021, https://www.mondaq.com/india/aviation/1108208/the-drone-rules-2021-an-unmanned-flight-into-unchartered-territory Accessed on February 6, 2022.
33. R K Narang, "Counter Drone System: An Opportunity for Self-Reliance", *India Foundation*, September 6, 2021, https://indiafoundation.in/articles-and-commentaries/coounter-drone-systems-an-opportunity-for-self-reliance/. Accessed on January 18, 2022.

Drone detection and neutralisation are the foundations of counter-drone technologies, which include both soft and hard kill solutions. The former entails jamming, spoofing, or forcing rogue drones to descend away from their designated target, return, or be captured by neutralising the control, navigation systems and sensors.

Saudi Arabia fired a three-billion-dollar Patriot missile to shoot down a $300 quadcopter.

Countering a drone attack becomes an even bigger problem when faced with a large number of tiny drones (swarm drones) where any kinetic energy weapon would cost too much, and also its effectiveness is limited. This is where directed energy weapons like lasers and microwaves come in. Therefore, cost effective technological solutions to counter this emerging sub-conventional warfare, in both defensive and offensive modes, are being developed in many countries, including India.

Counter-Drone Technology

Drone detection and neutralisation are the foundations of counter-drone technologies, which include both soft and hard kill solutions. The former entails jamming, spoofing, or forcing rogue drones to descend away from their designated target, return, or be captured by neutralising the control, navigation systems and sensors. Lasers, microwave systems, and physical destruction by missiles, firearms, or suicide drones are among the hard kill technologies being developed. The majority of current anti-drone systems are hybrid systems that include numerous detection and neutralisation methods.

Land-based and Airborne Counter-Drone Systems

Many land-based counter-drone systems are being developed globally. The Indian Navy acquired the Smash fire control system, manufactured by the Israeli company Sharpshooter, which can be placed on rifles and empower the soldiers with anti-drone capabilities. It is a capability

enhancer that enables the use of existing rifles/guns in the counter-drone role.[34] Small, armed drones, operating alone or in groups, can outsmart even an airborne platform and overcome their speed disadvantage by disguising their approach and employing artificial intelligence to route intelligently. Slow-moving manoeuvrable flying platforms such as helicopters and training aircraft, on the other hand, can defend themselves and provide airborne protection if outfitted with appropriate anti-drone equipment. While India is working on several land-based hybrid anti-drone systems, no plans for an airborne anti-drone system have been announced.[35]

Indigenous Development of Counter-Drone Systems in the Indian Public Sector

The detect-and-destroy technology for neutralising rogue drones (D-4 anti-drone system) was developed by the DRDO in 2019. This anti-drone system was deployed for VVIP protection during the bilateral visit of the United States President Donald Trump in 2020; the Republic Day Parades in 2020 and 2021; and Independence Day, 2020. According to the Defence Ministry, the Indian Navy signed a deal with the defence Public Sector Undertaking (PSU) Bharat Electronics Ltd (BEL) in August 2021 for the supply of the first indigenously developed Naval Anti-Drone System (NADS), which was developed by DRDO and manufactured by BEL.[36] The NADS, according to the report, detects and jams micro drones using radar, Electro-Optical/ Infra-Red (EO/IR) sensors, and Radio Frequency (RF) detectors. The DRDO's RF/Global Navigation Satellite System (GNSS) is said to recognise

34. Abhishek Bhalla, "Armed Forces Order Indian-Made Anti-Drone Systems Worth over Rs 300 Crore, More Contracts Awaited", *India Today*, September 3, 2021, https://www.indiatoday.in/india/story/armed-forces-order-indian-made-anti-drone-systems-worth-rs-155-crore-1848915-2021-09-03. Accessed on September 20, 2022.
35. Narang, n. 33.
36. PTI, "Navy Signs Contract with BEL to Procure India's First Indigenous Naval Anti-Drone System", *The Print*, August 31, 2021, https://theprint.in/defence/navy-signs-contract-with-bel-to-procure-indias-first-indigenous-naval-anti-drone-system/725726/. Accessed on January 18, 2022.

the controller's frequency, following the communications jamming. This anti-drone system offers the Indian armed forces both 'soft kill' and 'hard kill' options to combat fast-emerging aerial threats.

Acquisition, Collaboration and Contracts with Indian Private Players

In a short period of time, the armed forces have bought anti-drone systems built in India costing over Rs 300 crore. In September 2021, the Indian Air Force placed an order for anti-drone platforms worth Rs 155 crore with Zen Technologies, located in Hyderabad. It was awarded the contract to supply the systems within a year.[37] Zen Technologies' counter-unmanned aerial system detects, classifies, and tracks drones using passive surveillance, camera sensors, and neutralises threats by jamming drone communications. It is a multi-layer, multi-sensor architecture with modules including RF Based Drone Detection (RFDD), Video-based Drone Identification and Tracking (VDIT), Radar, Data Fusion and Command Centre (DFCC), Drone RF Jammer (DRFJ), and hard kill targeted at offering comprehensive security against drone attacks.[38]

BEL had reportedly teamed up with Grene Robotics to create an AI-based autonomous Operating System (OS) dubbed "air defence dome," having a multi-sensor multi-shooter counter-drone system. However, this system has neither been displayed nor deployed.[39] Big Bang Boom Solutions has developed an anti-drone defence system that includes RF and EO detectors as well as an RF jammer,[40] and Gurutvaa Systems Pvt Ltd has developed

37. Abhishek Bhalla, "Anti-Drone Plan: How India is Strengthening its Unmanned Warfare Power", *India Today*, September 7, 2021, https://www.indiatoday.in/india/story/anti-drone-plan-india-is-strengthening-its-unmanned-warfare-power-1850285-2021-09-07. Accessed on February 8, 2022.
38. https://www.zentechnologies.com/anti-drone-system-counter-drone-cuas.php. Accessed on February 8, 2022.
39. "Autonomous Defence Done for Wide Aerial Protection," *Grene Robotics*, December 10, 2020, https://grenerobotics.com/autonomous-defence-dome-for-wide-aerial-protection/. Accessed on February 8, 2022.
40. "Big Bang Boom Anti-Drone Defence System", *Big Bang Boom Solutions*, http://bigbangboom.com/our-projects/. Accessed on February 9, 2022.

a spoof emitter and a hand-held jammer that can be carried in a backpack as well as installed on a vehicle.[41] More firms such as VEM Technologies, Timetooth Technologies, and EDITH Defense Systems are joining counter-drone design and manufacturing, indicating that domestic production has a promising future.[42]

L&T has partnered with IdeaForge,[43] while Reliance Industries has acquired a majority stake in the Indian drone start-up Asteria Aerospace.[44] Adani Defence and Aerospace has teamed up with Israel's Elbit Systems to produce and sell its counter-drone equipment in India.[45] Jugapro, a firm known for selling hanger drones, has partnered with Fortem Technologies,[46] a US start-up, to offer its anti-drone devices. Many start-ups and small firms are working on this technology; however, large companies have made very little investment in counter-drone research and development, which needs to change. Apart from the hard and soft kill solutions, the rogue drone menace can be reduced by conducting successful intelligence operations to locate the operator, prohibiting the drone from taking off.

Integration of Counter-Drone System into Existing AD Infrastructure

The new anti-drone technologies would have to work with the IAF's current Integrated Air Command and Control System (IACCS). Another important component of the counter-drone ecosystem would be the

41. Grurutvaa, https://idex.gov.in/showcase-cpt/458. Accessed on February 9, 2022.
42. "Andhra Pradesh: TTD to Deploy DRDO's Anti-Drone Systems to Protect Tirumala Temple", July 24, 2021, https://swarajyamag.com/insta/andhra-pradesh-ttd-to-deploy-drdos-anti-drone-system-to-protect-tirumala-temple. Accessed on February 11, 2022.
43. "L&T to Offer Drone Technologies to Defence Forces", *Business Line*, February 7, 2020, https://www.thehindubusinessline.com/companies/lt-to-offer-drone-technology-to-defence-forces/article30760249.ece. Accessed on February 11, 2022.
44. "Reliance Buys Majority Stake in Drone Company", *Geospatial News,* May 6, 2020, https://www.geospatialworld.net/news/reliance-acquires-asteria-aerospace-with-51-78-stake/. Accessed on February 11, 2022.
45. "Adani Defence and Aerospace", https://www.adanidefence.com/unmanned-aerial-systems. Accessed on February 11, 2022.
46. "Jugapro Sky Dome Systems", http://jugapro.com/?page_id=5031. Accessed on February 12, 2022.

An AD network, made up of numerous security groups, with different traditions, training, and operation philosophies, on the other hand, would present new concerns that must be examined. Multiple detection and neutralisation systems developed by different governmental and private sector companies must be integrated to create a holistic counter-drone system.

coordination and integration of existing AD systems. An AD network, made up of numerous security groups, with different traditions, training, and operation philosophies, on the other hand, would present new concerns that must be examined. Multiple detection and neutralisation systems developed by different governmental and private sector companies must be integrated to create a holistic counter-drone system.

CHALLENGES IN INDIAN AVIATION ECOSYSTEM AND DELIBERATIONS

The preparedness of a country to conquer the emerging unmanned warfare is intrinsically linked to the capability of its aviation sector to design, develop, and construct UAVs in the country, especially the effectiveness of its aviation ecosystem. The Indian aviation sector has had its fair share of accomplishments, setbacks, and obstacles, and its aviation industry is still struggling to turn its indigenously developed and tested aviation plans into commercially viable products.[47] While India boasts of its renowned engineering institutions, R&D agencies, Defence Public Sector Undertakings (DPSUs), sophisticated armed forces, and a budding aerospace private sector,[48] its resilience is called into doubt by a lengthy history of incapacity to learn from errors in order to derive relevant lessons for future improvements. Its inability to obtain maximum technological benefits from defence and civil aviation acquisition deals implies that the strategy for technology acquisition must be reevaluated and adjusted.

47. Ibid.
48. The Indian government established the Defence Public Sector Units (DPSUs) to manufacture, overhaul and upgrade high-technology defence equipment, including aircraft and associated systems.

Some of the challenges are discussed in the following section.

For civil users, there is no designated aviation testing facility in India. The existing test facilities of the DRDO, DPSUs, and the defence forces are insufficient for private sector entrepreneurs to test their technologies during the development phase.

Lack of an Apex Aeronautics Authority

There are many organisations, including ministries [Ministry of Civil Aviation (MoCA), Ministry of Defence (MoD), Ministry of Science and Technology], defence forces, PSUs and R&D agencies (DRDO, BEL, HAL, etc.), private sector entities, and academia [Indian Institutes of Technology (IITs)/engineering colleges, etc.] working in the aeronautics sector. All these stakeholders are working in silos, which results in wastage or duplication of resources, lack of collective thought and a national integrated strategy. There is a need of an apex authority to integrate the knowledge, activities and experience of all the stakeholders, carry out a realistic assessment of the requirements, existing capabilities and Technological Readiness Levels (TRLs).

Lack of an Accessible Aviation Testing Facility

For civil users, there is no designated aviation testing facility in India. The existing test facilities of the DRDO, DPSUs, and the defence forces are insufficient for private sector entrepreneurs to test their technologies during the development phase. The use of these services by private sector users is governed by a variety of policies, some of which are confusing. [49] and the majority of them lack an online registration process. Because of the necessity to develop next-generation air traffic management systems as well as examine existing legislation and policies to support the inclusion of unmanned aerial systems, the demand for testing facilities has further increased.

49. "Testing Facilities for Private Sector, Department of Defence Production, Make in India", http://www.makeinindiadefence.gov.in/pages/test-facilities-for-private-sector. Accessed on March 15, 2022.

The "Users" Mindset: India's Historical Dilemma

The British had left India with a limited scientific and technology base, as well as no infrastructure suited to innovating and conducting research to build indigenous aircraft products. Their regulations instilled in Indians a "users" attitude and hindered "innovative and entrepreneurial" potential. The habit of using final products made Indians good customers but not risk takers, innovators, or product designers, which had a long-term negative impact on their psychology. For nearly four decades following independence, civil aviation manufacturing received no attention, which could have been a powerful catalyst in expanding it.

Leveraging the Civil Aviation Market

The large civil aviation sector in India provides a chance to acquire manufacturing technologies by acquiring deals. In 1990, India opened its civil aviation industry to private operators, resulting in a rapid increase in the size of the civil aviation market.[50] However, it did not take advantage of the large civil aviation market's leverage to acquire manufacturing technologies, establish Maintenance, Repair and Development (MRO) facilities, and strengthen its aviation ecosystem,[51] whereas countries with a much smaller civil aviation market, such as Malaysia, Singapore, etc. were able to establish MRO facilities, local manufacturing of aircraft, sub-assemblies, and other items.[52]

Under-exploited Private Sector in Aviation

Budding entrepreneurs and start-ups offer innovative ideas to the defence and aviation industries' severe challenges. They also have the ability to develop cutting-edge technologies that will offer India's defence forces

50. "Association of Private Operators", https://www.apaoindia.com/?page_id=185. Accessed on February 15, 2022.
51. Rajeev Satav, "The Challenges Facing India's Civil Aviation Sector", *The Indian Express*, May 4, 2016, https://indianexpress.com/article/blogs/the-challenges-facing-indias-civil-aviation-sector-2782612/. Accessed on February 15, 2022.
52. "Malasia Expands Aerospace Capabilities", *Asian Aviation*, October 1, 2010, https://www.asianaviation.com/articles/55/Malaysia-expands-aerospace-capabilities. Accessed on February 20, 2022.

an advantage. The defence forces, on the other hand, face a problem in leveraging the potential of young innovators and private sector start-ups. In India, the private sector's share of the defence sector is under 5 per cent, which is negligible.[53] In 2016, only 50-60 companies out of 2,500 registered with HAL participated in the sub-contract work on a regular basis.[54] While Medium, Small and Micro Enterprises (MSMEs) and start-ups have contributed to the creation of sub-systems for the Light Combat Aircraft (LAC), Advanced Light Helicopter (ALH), and UAVs, among other things,[55] larger private sector corporations have had minimal influence on the development of aviation products.

The government's initiative to increase private sector participation, on the other hand, has not yielded the expected outcomes. Manufacturers (Indian private sector firms) that design, develop, and manufacture civil aviation items are at a disadvantage compared to Indian enterprises (traders) that supply[56] foreign products in India[57] because of the following major reasons.

Complex Licensing Process

In India, MSMEs and start-ups in the aviation and defence industries face a complicated licensing process and stringent compliance requirements. Indian enterprises that offer foreign products require fewer licences and are exempt from severe manufacturing compliance requirements. This causes financial hurdles for Indian manufacturers and has an influence on their

53. Sandeep Unnithan, "Unmade in India", *India Today*, February 22, 2017, https://indiatoday.intoday.in/story/defence-industry-india-arms-import-military-requirements-parrikar-make-in-india/1/889372.html. Accessed on February 25, 2022.
54. T Suvarna Raju, Chairman HAL, in his address at the 11th International Conference on Energising Indian Aerospace Industry: The Changing Environment, at New Delhi on September 2, 2016.
55. "Challenges to MSME", https//www.indiansmechamber.com/challenges_to-msme.php. Accessed on March 5, 2022.
56. Peerzada Abrar and Biswarup Gooptu, "70 percent of Defence Machinery Imported while Indian Defence Companies find Government a Hindrance", February 15, 2013, http://economictimes.indiatimes.com/industry/indl-goods/svs/engineering/70-per-cent-of-defence-machinery-imported-while-indian-defence-companies-find-defence-a-hindrance/articleshow/18508801.cms. Accessed on March 5, 2022.
57. Ankit Mehta, CEO, ideaForge, interview with Group Captain R K Narang, author of the book, *India's Quest for UAVs and Challenges*.

India is home to several IITs and other engineering schools but these colleges and universities lack aviation-related facilities like functional models of aircraft, engines, and associated systems, labs, wind tunnels, trial and testing sites.

business economic viability, particularly when competing against established global competitors.[58]

Uncertain Quality Requirements, Unassured Orders and Insecure IPRs

Most consumers are concerned about cost overruns and lags in the finishing of Design and Development (D&D) initiatives. Modifications in aviation projects usually take a long time. The difficulties have been exacerbated by frequent changes in the equipment's Qualitative Requirements (QRs)[59] and the lack of assured orders.[60] This can be linked to poor project management and a lack of stakeholder accountability.[61] In addition, payments to private sector suppliers are sometimes delayed, causing them difficulties.[62] Private enterprises are also concerned that their systems and sub-assemblies' Intellectual Property Rights (IPRs) are not effectively secured.

Archaic Academic Institutions

The nation's academic institutions play a critical role in studying and conducting scientific research in order to build futuristic technology. India is home to several IITs and other engineering schools but these colleges and universities lack aviation-related facilities like functional models of aircraft, engines, and associated systems, labs, wind tunnels, trial and testing sites,

58. Freezing of Final Design, 3.7.1.2. p26, MoD Report 10-2010-11, https://cag.gov.in/sites/default/files/audit_report_files/Union_Performance_Commercial_Activities_Public_Sector_Undertakings_10_20120_chapter_3.pdf. Accessed on March 10, 2022.
59. Ibid.
60. "Self Reliance in Defence Production", *ASSOCHAM India*, https://www.pwe.in/assets/pdfs/publications/2014/self-reliance-in-defence-production.pdf. Accessed on March 10, 2022.
61. K Tamilmani, former director, CEMILAC, in a telephonic interview with Group Captain R K Narang. Accessed on March 10, 2022.
62. Dipak Mondal, "Payment Blues", Businesstoday.in, July 17, 2016, https://www.businesstoday.in/magazine/corporate/companies-working-for-the-government-under-financial-stress/story/234234.html. Accessed on March 10, 2022.

etc. which makes it difficult to conduct research and support the D&D of aviation products. Their curriculum is primarily theoretical, and they need to include more practical content and expand their participation in aviation projects.[63] These institutes do not meet international standards in terms of education and research. Most of the researchers and academic practitioners are not paid enough and this profession is not focussed upon much in India. Therefore, most of the students interested in pursuing it as a full-time career either shift to a country with a better research ecosystem or take up other jobs.

Military Aviation Certification and Quality Assurance

Military aviation certification and quality assurance are handled by the Centre for Military Airworthiness and Certification (CEMILAC) and the Director General of Aeronautic Quality Assurance (DGAQA).[64] CEMILAC begins certification after obtaining a specific request from the users,[65] such as the Indian defence forces.[66] A few goods with common civil military applications, such as antennas, batteries, connectors, fuel, oil, and so on, have been certified and QA'd by these agencies[67] They do not, however, provide certification and quality assurance for military aviation products developed by Indian private sector enterprises unless the defence Services have projected a need for them. As a result, they are compelled to obtain certification from the United States or other Western countries, partner with global aviation companies, or sell their innovative technologies to them: hence, India loses high value intellectual capital.

63. "Why Do India's IIT Do So Badly on Some University Rankings?", May 15, 2014, https//blogs.wsj.com/indiarealtime/2014/05/15/why-do-indias-iits-do-so-badly-on-some-university-rankings/. Accesses March 10, 2022.
64. "DGAQA", http://dgaeroqa.gov.in/about_us.html. Accessed on March 12, 2022.
65. "CEMILAC", http://www.drdo.gov.in/drdo/labs1/CEMILAC/English/indexnew.jsp?pg=homepage.jsp. Accessed on March 15, 2022.
66. Brief on Testing and Certification Procedures in Military Aviation Sector, HA DGAQA, MoD, http://dgaeroq.gov.in/Data/Test%20certification.pdf. Accessed on March 17, 2022.
67. Tamilmani, n. 61.

Artificial intelligence, sensors, advanced weapons, and navigation technologies have improved the precision, lethality, and efficacy of small armed drones, allowing them to function intelligently and carry out complicated missions alone, collaboratively, and in swarms.

Insufficient Investment in R&D

India's entire investment in R&D is less than 1 per cent of the GDP, far less than the 2.5-3 per cent of the GDP invested by the world's leading industrial nations.[68] In terms of defence products, India's self-reliance index is approximately 30 per cent. The assessment committee, led by Dr. APJ Abdul Kalam,[69] had suggested that 10 per cent of the defence budget be invested in R&D to boost indigenisation content from 30 per cent in 1995 to 70 per cent by 2005.[70] There was no significant rise in R&D expenditure, and the indigenisation index did not improve.

Keeping up with the Futuristic Technologies

Artificial intelligence, sensors, advanced weapons, and navigation technologies have improved the precision, lethality, and efficacy of small armed drones, allowing them to function intelligently and carry out complicated missions alone, collaboratively, and in swarms. While drones can be countered with drones and India is developing several land-based hybrid drone systems as well, counter-swarm drone technology is still in progress and there has been no announcement for an airborne anti-drone system. The eminent contributors in this field should take note of all such emerging mechanisms and begin working on their indigenous development.

Deliberation on Technology Development Programmes

Many technological development initiatives are being undertaken, including the Department of Science and Technology's Device Development

68. "Move to Increase R&D Expenditure to Two Percent of GDP", April 23, 2015, http://pib.nic.in/newsite/PrintRelease.apx?relid=118574. Accessed on March 20, 2022.
69. Dr APJ Abdul Kalam later became the president of India.
70. Rajiv K Bhatia and Vijay Sakhuja, "Indo-Pacific Region, Political and Strategic Prospects", p. 161, http://bit.ly/2k9spGI. Accessed on March 20, 2022.

Programme (DDP), the DRDO's Technology Development Fund (TDF), and the Global Innovation and Technology Alliance (GITA), which is a Public Private Partnership (PPP) programme. Another initiative taken by the Government of India to contribute towards the indigenous modernisation of India's defence industry is iDEX (Innovations for Defence Excellence). By involving industries such as start-ups and MSMEs, individual innovators, academics, R&D institutes, iDEX aspires to promote self-reliance and nurture innovation and technological development in the defence and aerospace sectors. iDEX has teamed with the country's premier incubators to give hand-holding, technical support, and mentorship to iDEX competition winners. Problem Statements (PS) from the armed forces and Ordnance Factory Board/Defence Public Sector Undertakings (OFB/DPSUs) are posted on the Defence India Start-up Challenge (DISC) website for entrepreneurs to solve.

The Mehar Baba Competition, which was established in 2018 and is organised by the IAF, is one of India's most forward-thinking innovation ventures. The second edition of this competition was announced by the defence minister on April 6, 2022, during the three-day Air Force Commanders' Conference.[71] In July 2021, the Ministry of Electronics and Information Technology (MeitY) launched the BSF High Tech Undertaking for Maximising Innovation (BHUMI) Grand Challenge in collaboration with the Border Security Force (BSF) to identify impactful solutions from start-ups to address three problem statements, one of which is the development of anti-drone technology.[72]

These competitions make it easier to turn an idea into a product and this is exactly what India requires.[73] Conducting such programmes and

71. https://frontline.thehindu.com/dispatches/defence-minister-rajnath-singh-launches-the-meher-baba-competitionii-aimed-at-the-growing-indigenous-drone-industry/article38469544.ece#:~:text=Defence%20Minister%20Rajnath%20Singh%20launched,objects%20on%20aircraft%20operating%20surfaces%E2%80%9D. Accessed on July 2, 2021.
72. "BHUMI, BSF Grand Challenge", https://app.thebizplanner.com/public/application/inc/60ddb7ec76b190674a4117e5. Accessed on August 2, 2021.
73. IAF's Mehar Baba Prize, "India's First Competition in Defence Sector: All You Need to Know", *The Indian Express,* October 16, 2021, https://indianexpress.com/article/india/iafs-mehar-

A robust and conducive aviation ecosystem, synchronisation among stakeholders, and government backing play a vital role in aiding design and development of UAVs, which is a crucial part of the strengthening of a country's capabilities to triumph in unmanned warfare.

increasing financing can greatly benefit the design bureaus of the defence forces, as well as the technical departments of the police, security forces, and MoCA.

INDIA'S WAY FORWARD

A robust and conducive aviation ecosystem, synchronisation among stakeholders, and government backing play a vital role in aiding design and development of UAVs, which is a crucial part of the strengthening of a country's capabilities to triumph in unmanned warfare. The higher education system, a high innovation index, public-private sector synergy, and an enabling environment are all required for indigenous product development competence. It is critical to work on shoring up these cornerstones. The 'Make in India,' offsets, collaborations, and joint ventures should not be selected by the Original Equipment Manufacturer (OEMs), but rather after a comprehensive analysis of existing capabilities, identification of capability gaps, and development of a technology acquisition framework. It is felt that the roadmap proposed in the book, *India's Quest for UAVs and Challenges* authored by Group Captain R K Narang merits attention. After having deliberated on the need and challenges of building UAV and Counter-Unmanned Aerial Vehicle (CUAV) capability, the following is recommended.

Establishment of National Aeronautics Commission

To fully harness the potential of the Indian aviation sector, a higher authority like the National Aeronautics Commission (NAC), can be established. The NAC would fill in the gaps by coordinating and synchronising the

baba-prize-indias-first-competition-in-defence-sector-all-you-need-to-know-5404071/?fbclid=IwAR1vGCGcfhnw7SmzscDHzh7lYOU-9uFhNRQYQWu4x7nq40OLI1c2FZQpxKY. Accessed on July 24, 2021.

efforts of various stakeholders involved in indigenous research, design, development, and production of aviation platforms and related technologies.[74] This would help in overcoming all the challenges present due to the absence of an apex aeronautical authority, thereby aiding in timely funding and simplifying the decision-making process.

Integration of civil-military aviation manufacturing, according to top aviation manufacturers' experiences, is beneficial in boosting production scale, lowering costs, generating competitive business models, and utilising technology benefits.

Setting up of Centres of Excellence

Different DRDO, NAL, and HAL laboratories are working on similar products, and some of these laboratories are placed in different states. This is ineffective in terms of establishing centres of excellence, or creating knowledge and a vendor base. To integrate R&D, prevent duplication, and save precious resources, it is suggested that suitable research laboratories or groups of laboratories in proximity be identified for designation as centres of excellence, and investigation and design of comparable products be combined, regardless of the ministry or organisation.

Bolstering Civil-Military Synergy

Integration of civil-military aviation manufacturing, according to top aviation manufacturers' experiences, is beneficial in boosting production scale, lowering costs, generating competitive business models, and utilising technology benefits. In India, both have different development plans and sourcing. India could investigate combining the design, development, and manufacture of both civil and military unmanned aircraft, sensors, and supporting systems. Establishing a framework between the MoD and other ministries [notably the Ministry of Home Affairs (MHA)] to achieve

74. "Need for Setting up Aeronautics Commission Stressed", September 26, 2007, http://articles.economictimes.indiatimes.com/2007-09-26/news/28415518_1_aeronautical-society-national-aeronautics-policy-aeronautical-community. Accessed on March 25, 2022.

synergy in the procurement of some of the pre-identified high-value and high-technology items is proposed.

Creation of an Accessible Aviation Testing Facility

To overcome the challenges posed by lack of accessible testing facilities, the development of an Aviation Testing Agency (ATA) is recommended. This agency should have the infrastructure needed and could serve as a single point of contact for testing innovative and indigenously developed civil and military unmanned aviation products by private entrepreneurs.

Investment Increment in R&D

It would be preferable to increase R&D spending to 2.5 percent of the GDP.[75] Investment in R&D would help to develop the domestic economy, reduce reliance on imports, and produce jobs in the country. This will also encourage more students to pursue academic research as a full-time career in India.

Equitable Policy Measures for Private Players

Policy measures should be implemented for fair and mutually advantageous revenue sharing arrangements among private and public sector enterprises, with each partner's Intellectual Property Rights (IPRs) for jointly developed technology protected. Orders for indigenously designed and created products should be placed in sufficient numbers. The procurement and technological development strategies for the short and long terms, as well as the amount to be procured, must be made public. Financial and technical assistance could be provided to noteworthy innovations and prototypes in order to turn them into operational products.

To encourage participation in aircraft manufacturing, the time it takes to approve a collaboration or assign contracts to the private sector should be

75. R. K. Narang, *India's Quest for UAVs and Challenges* (New Delhi: KW Publishers Pvt Ltd, in association with the Centre for Air Power Studies, 2020), p. 391.

reduced and the military certification procedure should be streamlined. The system for correcting stakeholder accountability as well as following an incremental design upgrade by developing distinct design blocks is required. The design of a product in development could be frozen at pre-determined points in time. Following the design freeze, future revisions, alterations, and upgrades may be implemented in blocks.

Establishing an Institute of Aeronautics

India requires a dedicated aeronautics institution with the necessary facilities and the ability to encompass aviation research, design, development, production, product support, and other facets of aviation education all in one location.[76]

To develop powerful future warfare systems and networks, not just for India but also for export to friendly nations, the trajectory of private players being employed tactically as sub-contractors rather than as strategic partners in the development of aviation systems must be reversed and collaboration with academic institutions should be encouraged.

CONCLUSION

The aviation sector India is predominantly a service-led sector. Its industry has a promising capacity to design and develop unmanned aerial components, however, it is creating distinct aspects of these technologies in silos. If India's UAV sector aims to become a design and development-led high value sector, the defence forces will have to be more involved in the design and development process. To develop powerful future warfare systems and networks, not just for India but also for export to friendly nations, the trajectory of private players being employed tactically as sub-contractors rather than as strategic partners in the development of aviation systems must be reversed and collaboration with academic institutions should be encouraged.

76. "Indian Institute of Space Science and Technology", https://www.iist.ac.in/sites/default/files/placementcell/Placement.pdf. Accessed on March 25, 2022.

The advent of UAVs has changed the perception and nature of warfare dramatically and it is continuing to do so at an exceptionally high pace with the ever-evolving developments in technology. The force formations and technologies that will define the character of future wars must be prioritised so that India does not end up fighting tomorrow's war with yesterday's strategies and armaments. India will be ready, not just to conquer but to triumph in unmanned aerial warfare if it utilises its potential by overcoming administrative, bureaucratic, and policy barriers and seizing control of indigenous ventures.