

Indian Drone Ecosystem

Need to Innovate to Dominate

*Rajan Desai**

Operation Sindoor saw Pakistan launch massed drone attacks which were neutralised by the Indian counter-unmanned aircraft system grid. Pakistan and its all-weather friends, China and Turkey, most likely will learn from this misadventure and evolve better drone designs, coupled with tactics, techniques and procedures, for combat. India needs to prepare for combatting the drones that they throw at it tomorrow and at the same time, build innovative drone capabilities to enhance offensive response options. Drones have incrementally evolved over time in India. However, some technologies can exponentially enhance their capabilities and utility. Does the Indian drone ecosystem have what it takes to deliver? Does success till now guarantee similar performance in future? What are the technologies and innovations that the Indian drone ecosystem can invest in its quest for global domination? What lessons can we take from countries that are leading drone innovations and development? This article makes an attempt to find answers to a few of such questions.

Keywords: *Drone Technology; Indian Drone Ecosystem; Innovations; R&D; Future Wars*

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INTRODUCTION

Operation Sindoor, launched on 7 May 2025, was India's answer to Pakistan-sponsored, terrorist-initiated massacre at Pahalgam on 22 April 2025. The three days of combat saw India giving a bloody nose to the adversary, striking at will. Thanks to the media glare, the combat was relayed live into the homes of over a billion people. Especially eye-catching was the massed drone launches by Pakistan, which were effectively beaten back by India's integrated counter-unmanned aircraft system (c-UAS) and air defence grid.¹ Over 600 drones were destroyed by India across the entire international boundary.²

Although Pakistan does have a fledgling but potentially capable indigenous drone ecosystem, it had procured these drones with the support of its global allies, like Turkey and China. These commercial drones, procured at the last minute, could not dent the superior reactions of India. However, being a fast learner, Pakistan has the capability to upgrade its drone industry with active foreign help. Therefore, while continuing to fight drones which an adversary throws at the country today, it is rather vital for India to prepare for the drone wars of tomorrow. Moreover, possessing innovative drone capabilities will further India's stated quest to dominate the global drone landscape, as well as enhance its options for their use against any adversary, apart from leveraging their dual-use utilities in other fields.

The drone ecosystems, both global and Indian, are flourishing based on increased demand, enhanced funding, focused research and development (R&D), along with progressive regulatory framework. The 'Atmanirbhar Bharat' (self-reliant India) initiative and the ban on import of drones have further bolstered the Indian drone market. The global drone industry is expected to grow at a Compound Annual Growth Rate (CAGR) of 20 per cent to reach US\$ 91.3 billion by 2030.³ Correspondingly, the Indian drone industry is projected to grow at 44 per cent CAGR till 2030 to reach US\$ 4.9 billion.⁴ Another estimate pegs the Indian drone industry to reach US\$ 11 billion by 2030, accounting for over 12 per cent of the global drone market.⁵ However, whether growth in the Indian drone ecosystem leads to a corresponding increase in innovations and capacity-building practices in drone technology needs to be seen.

Drone technology is rapidly evolving with emphasis on increased autonomy, enhanced endurance/payload, intuitive Human–Machine Interface (HMI), advanced sensors, coupled with integration of Artificial Intelligence (AI) and 5G communication. These changes are likely to impact the utility of the drones only incrementally. However, there are innovative

ideas which can exponentially enhance the capabilities and utility of drones. This article will look at few such concepts. Additionally, an assessment of the indigenous drone industry landscape will assist in gauging the readiness of the Indian drone ecosystem in adopting these innovative concepts. Some practical and actionable recommendations for making the Indian drone ecosystem future-ready will also be discussed.

NOVEL CONCEPTS AND DESIGNS

Cutting-edge technology is pushing the frontiers of drone innovations. Let us now see some of these distinctive drone concepts and designs.

Shape Shifter

Imagine a drone which can modify its shape in flight! The shape shifter will be able to change its shape based on the environment around it. It may squeeze through a hole or window grill, and also manoeuvre through foliage, by folding its arms. Further, its control system can adapt to the altered position of its parts mid-flight, carefully continuing its operation. Presently, the prototype can shift its cross (X) shape into an H, or a T or an O, and its flight control can handle all these morphologies. The shape is selected by the operator as of now and work is on to make it autonomous, that is, the drone will adopt a different shape to fit the obstacle it encounters in field while maintaining steady flight. Efforts are on to enable the drone to shift its shape in all three dimensions, thus increasing versatility. Furthermore, the drone has capability to carry payload. It has been developed by researchers in Switzerland.⁶

ModQuad

This concept refers to a quadcopter which can physically connect with other quadcopters in flight. By doing so, the ModQuad, or modified quadcopter, aims to join forces or collaborate to accomplish tasks which are beyond individual capability but achievable jointly. These quadcopters can create large forms by combining mid-air and separate post completion of the mission. This concept, developed by researches in University of Pennsylvania, the United States (US), can revolutionise the logistics drone market where larger payloads are carried by merely combining smaller logistics drones.⁷ The complex task is to integrate obstacle avoidance capabilities and proximity sensors with flight path adjustments, which challenges the algorithm exponentially when done at large scale. The interlocking also allows better

power or battery management while facilitating adaptable operations for such drones.⁸

Join and Split Swarm

The Chinese are taking this capability to a new level with a swarm of combat drones capable of mid-air joining and splitting. It has immense potential as counter-drone defence strategies are tailor-made for specific threats. Thus, if the swarm expands in flight, it can strain the already scarce counter-drone resources while creating a shock effect. The perceived inefficiencies while combining individual drones has been overcome with claims of doubling the flight efficiency of individual drones. Not only does the collective range and speed of the combined drones increase but the individual drones themselves exhibit a 40 per cent increase in their efficiency post separation. The Chinese team has made significant progress in operationalising this concept of combining multiple single-blade drones into one coherent unit.⁹ While the West did attempt to apply this innovative principle to drone design, it was not successful in overcoming the challenges of task complexity and energy/payload constraints. This drone is inspired by the Maple seed design available in nature.¹⁰

Flimmer—Fly and Swim

The Naval Research Lab of the US is developing this flying swimmer drone, also known as Flimmer. It can transform from an unmanned aerial vehicle (UAV) to an unmanned underwater vehicle (UUV) with no special preparation. This means that within the same mission, it is able to take on roles of a UAV or a UUV based on the environment of operation. The drone can be exploited for either intelligence, surveillance and reconnaissance (ISR) or strike capabilities, apart from potential utility in sensor deployment, environment monitoring and disaster relief operations.¹¹ Similar concept applied to land dimension has drones which can crawl, run or bounce over land and hover or take flight as the environment demands. This allows the drone to conserve its power, thus increasing its endurance, while it can possibly avoid detection due to its low trajectory profile. Imagine such drones coming across from Pakistan. They would have likely penetrated the Indian border areas from land, while our c-UAS systems were looking at the skies!

Ionic Wind

This potentially silent propulsion technology harnesses the flow of ions or charged particles in air. These ions, when charged with high voltages due to

the battery present on the drone, create a fluidic stream of air rushing to the negative electrode at the back of the drone, thus providing lift and propulsion. Normally, a drone has many moving parts, but this drone boasts of having none, thereby simplifying the structure. It also makes no noise due to absence of any motors or engine. The prototype, developed by Lincoln Laboratory at the Massachusetts Institute of Technology (MIT), has completed many short-distance flights.¹² A Florida-based company, Undefined Technologies, is making a drone—Silent Ventus—using the same technology and it claims to have flown for 4.5 minutes. It is in process to design drones for urban delivery market due to its silent operation capability.¹³ In 2022, the company had claimed that the drone was planned for commercial roll-out by 2024, but this has not happened till date. The delay only goes to prove the ‘valley of death’ which all technologies have to cross before being scaled for production.

Wireless Power Transfer (WPT)

All drones powered by batteries or engines have to land in order to recharge or refuel. However, through WPT, it is feasible to transmit the required power to the drone through wireless means. The drone uses high-voltage power lines to charge its batteries while in flight. It also selects the flight path depending on the availability of power lines, which, in turn, increase its radius of operation and utility.¹⁴ Other methods include capacitive and inductive charging stations, which are effective over short distances, as well as laser charging, which is potentially effective over longer distances. The challenge though is to prevent electromagnetic beams from scattering, thereby leading to path and power loss. The Defense Advanced Research Projects Agency (DARPA) is also working in this field, but there are immense safety and technology issues that have to be overcome.¹⁵ A small drone prototype has already been made at Imperial College of London, where the drone hovers near the charging pad and has potential for endless flight time.¹⁶ GuRu Wireless Technologies have recently demonstrated charging of a drone 30 feet away.¹⁷

Other Innovative Designs

There are other innovative designs which have a similar impact on the utility of drones. For instance, the perch and stare drone considerably increases the time over target as the drone clings or sits on nearby structures, like walls and tree branch, to carry out persistent surveillance. Such drones have been used by the Israel Defense Forces (IDF) effectively in urban combat.¹⁸ The JetQuad uses miniature jet engines and thrust vector nozzles for propulsion in flight.

Apart from reduced size, it also boasts increased speed and simple design due to less moving parts.¹⁹ A turbo jet or a ram jet may further increase the speed to permit supersonic flights, thus reducing travel time. Ornithopters are drones based on bird design with wings that can be spread or retracted based on the aerodynamic requirement. They have the potential to outperform current fixed and rotary-wing drones. After all, birds have evolved over millions of years, proving them to be best adapted to aerial flight.²⁰

Tube launch rotary-wings drones have folded rotors when loaded into the launch tube. The rotors spring out on launch, thus enabling transition from launch trajectory to controlled flight. These drones can also be deployed from moving platforms, enabling their utility in mobile operations.²¹ Invisible drone refers to concealment techniques to make the drone merge with its surroundings, thereby reducing its detection. Efforts are on to increase the spectrum coverage, thus enabling drones to go undetected in visible and infrared range, as well as to allow concealment from multiple directions. Meta-materials are also being used to shape the airframe so as to regulate electromagnetic wave propagation.²²

It is believed that the precursor to modern-day helicopters was the 'Aerial Screw' designed by Leonardo da Vinci in the 15th century. The available technology and materials then prevented its fabrication and flight as it was truly ahead of its times. However, researchers have recently proved that not only does it work, but it can also be harnessed to make quieter and stealthier drones today.²³ Just like the Aerial Screw, the above-mentioned innovative drones may be waiting for their time!

INDIAN DRONE ECOSYSTEM: CHALLENGES AND OPPORTUNITIES

India has traditionally been a defence equipment importer for well-known reasons. It is only in the last two decades that some impetus has been given to cultivate home-grown innovations and solutions. The innovation and indigenous manufacturing ecosystem is still nascent. Hence, the question is that are such innovations feasible in India? This section critically analyses the drone landscape to find answers.

Trajectory of Indigenous UAV Development

In India, it was in the 1980s that the Defence Research and Development Organisation (DRDO) began to pursue indigenous UAV development with projects, like the tactical surveillance UAV, Nishant, and the target drone, Lakshya. These initiatives added to its experience in developing

avionics and aero-engine technology, but led to major challenges like lengthy developmental cycles and difficulties in meeting rigorous military requirements. The initial Medium-Altitude Long-Endurance (MALE)-class of UAV developed was Rustom, which later evolved into the TAPAS-BH-201. It successfully demonstrated certain capabilities, like autonomous take-off and landing (ATOL), but ultimately failed to meet essential Service Qualitative Requirements (SQRs) for endurance and altitude. This mission mode project was, hence, foreclosed in early 2024.²⁴

The setback highlights gaps in indigenous propulsion, battery technology and airframe design. The DRDO, in collaboration with private defence industry, is currently working on development of Archer-NG (MALE UAV) and Ghatak (stealth combat drone), apart from swarms and loitering munitions. The subpar performance of the DRDO in this domain till now can be ascribed to frequent design changes, technology denials and inadequate expertise of civil manufacturers, leading to long delays. However, delays and failures are part of innovation and indigenisation process. Hence, part attribution to poor management and lack of accountability cannot be refuted.²⁵

Role of Defence Services

The late Defence Minister Manohar Parrikar's comparison of the SQRs to Marvel comics was a sharp, yet humorous, critique, which highlighted the military's tendency to draft 'fantastical' or 'gold-plated' specifications. These often combined the best, mutually contradictory features of several global systems, resulting in impossible demands that no single vendor could realistically meet.²⁶ The trajectory of UAV development in India was also negatively impacted by this tendency, where the 'best available globally' became the enemy of the 'good available locally'. Hence, the defence services ended up procuring UAVs and loitering munitions mainly from Israel (Searchers, Herons, Harop, Harpy, etc.), while overlooking the comparatively modest initiatives of the DRDO mentioned earlier.

Post the government's 'Atmanirbhar Bharat' initiative announced in 2020, the urgent need for realistic, trade-off-conscious SQRs to boost the 'Make in India' mission was realised. The period coincided with the increased employment of UAVs and drones in various global conflicts, like the Nagorno-Karabakh war or Saudi Aramco refinery strikes, thus leading to a boom in their demand globally. The Indian Defence Services chose the 'good available locally' over the 'best available globally', leading to procurement of indigenous drones. The drone industry too responded through positive

participation and provided innovative drone products, albeit with minimal indigenous content (IC). Increased utility of drones in civilian fields, like photography, inspections, delivery and logistics and agriculture, also gave a fillip to their demand.

Drones Inducted in Defence Services

For long-range ISR, the Indian defence forces hold MALE Searcher and Heron UAVs, procured from Israel. Recently, Heron Mk II, enabled with satcom and weapons delivery, has been acquired.²⁷ Plus, the decision to upgrade existing Herons with satcom and weapon-carrying capability through Indian defence manufacturers looks for an indigenous solution.²⁸ As of now, no high-altitude long-endurance (HALE) UAVs are in the inventory, but a total of 31 US MQ-9 Reaper UAVs (15 Sea Guardians for the navy and eight Sky Guardians each for the army and the air force) have been contracted with delivery by 2028. Out of these, 21 are to be assembled in Indian facilities.²⁹ For short-range ISR needs, the Indian Army holds the ideaForge Switch and Zolt drones,³⁰ plus AeroArc-manufactured Trinetra.³¹ In addition, 65 tactical runway-independent remotely piloted aircraft systems, with endurance of over 6 hours, are in pipeline.³² Further, to meet the all-terrain and task-specific requirements of field formations, process is afoot to procure 1,000 unmanned surveillance helicopters, 750 remotely piloted aerial vehicles and 80 mini-remotely piloted aircraft systems.³³

As far as loitering munitions are concerned, Israel-made Harop and Harpy are being held by the Indian Air Force.³⁴ SkyStriker loitering munition and precision attack loitering munition (PALM) have been inducted for long-range targeting. For shorter range, Warmate from Poland and indigenous Nagastra from Z Motion and Solar group have been procured.³⁵ Para (Special Forces) battalions hold the US-made nano drone, Black Hornet.³⁶ Heterogeneous and homogeneous swarm drones from NewSpace and Raphe mPhibr are also held for ISR and targeting.³⁷ In addition, logistics drones are being inducted, including for high-altitude areas.³⁸ Evidently, most of the drones are procured from foreign sources or with foreign collaboration, with almost nil technology or intellectual property benefits to India. Those manufactured indigenously have negligible indigenised content, with local effort relegated to smaller peripheral parts only.

Recent Government Initiatives

The government has been the main driver for drone industry in India. With the resolve to make India a global drone hub by 2030, a host of schemes

have been launched to encourage indigenous drone production, including the Production Linked Incentive (PLI) scheme to enhance indigenous value addition and the monetary grant programme for purchasing agricultural drones (2022).³⁹ The SVAMITVA scheme has encouraged drone land survey. The ‘SwaYaan—Capacity Building for Human Resource Development in Unmanned Aircraft Systems’ (drone and allied technologies) initiative has also positively impacted skill development in drone services sector. Under this initiative, over 14,000 beneficiaries have been trained. Notable achievements have been: launch of an MTech in UAS engineering at the Indian Institute of Technology (IIT) Kanpur; initiation of multiple minor degree programmes; and successful conduction of numerous workshops.⁴⁰ As of early 2025, there were over 29,500 registered drones and more than 22,400 certified remote pilots, up from minimal numbers in 2020. This rapid, policy-driven expansion has led to over 96 type-certified drone models, with a strong focus on agriculture (65 models).⁴¹ A Rs 20 billion (US\$ 234 million) scheme is on the cards, way higher than the Rs 1.2 billion PLI arrangement mentioned earlier. It aims to have at least 40 per cent of key drone components made indigenously by 2028.⁴²

Drone Regulatory Framework

India was early off the blocks to create a drone regulatory framework with the launch of Drone Rules, 2021 and its further amendments in 2022, which did away with drone pilot licence. The Drone Airspace Map, freeing up to 90 per cent of the Indian airspace for flying drones up to 400 feet, and the UAS Traffic Management (UTM) policy, published in 2021, further aimed at integrating drones in the national airspace. The drone certification scheme, to make type certification of drones easier, and the drone import policy framework, banning outright import of drones and freeing up import of drone components, were launched in 2022.⁴³

All these regulatory initiatives can only facilitate indigenous manufacture and use of drones today, albeit based on their effective implementation. India’s drone regulations, which have evolved from a disjointed, clearance-based system to a structured, risk-based, digital-first approach, may be considered more proactive and comprehensive than many other nations’ policies. However, certain issues, such as beyond visual line of sight (BVLOS) operations, data governance policies, integration with telecommunication networks, aligning to international standards and more stringent implementation of import ban, require further impetus.

Testing, Certification and Standards

India's drone testing infrastructure is structurally aligned with global standards as the country has implemented mandatory certification, defined testing parameters and authorised third-party testing bodies. However, India lacks drone flight testing infrastructure to support its mission of becoming a global drone hub by 2030.⁴⁴ The Defence Testing Infrastructure Scheme was launched by the Ministry of Defence (MoD) in 2020 with an outlay of Rs 400 crore (approx. 54 million US dollars then) for creating state-of-the-art testing infrastructure in partnership with private industry. It envisaged setting up of six to eight Greenfield Defence Testing Infrastructure facilities required for defence and aerospace-related production.⁴⁵ The first drone testing infrastructure was to be established in Tamil Nadu.⁴⁶ Although memorandums of understanding (MoUs) were signed by the MoD in July 2024 for three sites each in Uttar Pradesh and Tamil Nadu, the overall progress has been very slow.⁴⁷

On the positive side, ANRA Technologies' 100-hour flight programme in 2021, in Etah district and at the IIT Ropar campus, involved BVLOS drone delivery trials. It was conducted with its partner, Swiggy, to collect data for the Directorate General of Civil Aviation (DGCA). The project, which included over 350 sorties and used multirotor drones and ANRA's SmartSkies software platform, successfully completed 1,100 kilometre (km) of incident-free operations. Apart from demonstrating the potential for commercial drone delivery, it also paved way for future drone regulations and services.⁴⁸ Similar testing was done in conjunction with a few other companies, like ShopX, SpiceXpress, Throttle Aerospace and Dunzo.⁴⁹ However, sans a definite time-bound implementation plan and a focus on integrated flight testing facilities, above-mentioned efforts are unlikely to have a significant impact.

Innovations in Drone Sector

The recently launched National Innovation Challenge for Drone Application and Research (NIDAR) aims to connect innovators with industry. With Rs 40 lakh (4 million) prize, start-up incubation and industry mentorship, it aims to provide students with career opportunities and skills in the growing drone ecosystem.⁵⁰ Additional innovation impetus for drones for defence is given through the Innovations for Defence Excellence (iDeX) scheme; Make I, II and III routes; and Army Technology Board projects. However, is the drone industry actually dedicating adequate resources to innovations

or is it busy focusing on business profits? Companies, like Bharat Electronics Limited and Hindustan Aeronautics Limited, spend a meagre 6–8 per cent of their revenue on R&D activities.⁵¹ A pioneering drone company in India, ideaForge Technologies, claims to have spent around 22 per cent on R&D in fiscal year (FY) 2024–25.⁵² Although India has a comprehensive range of types of drone manufactured, the market focus is primarily on defence, security and agriculture. There is very little traction in the low-cost but high-volume recreational and consumer segment. The delivery and cargo domain is still under testing phase, though there is some progress, as seen earlier. We need innovation in design and core technology (real-time decision making, swarm intelligence, sense and avoid, real-time kinematics, denied/confined environment guidance, multi/hyperspectral sensors, etc.), as well as advanced applications (digital twin creation, automated inventory management, precision spraying and seeding, etc.).

Battle-tested Systems

The field evaluation tests prior to induction of drones in the Indian Defence Services are very stringent and are conducted in varied terrains, like high-altitude areas and deserts. BonV Aero, a logistic drone company, achieved a world record for highest flight with a drone carrying 30 kilogram (kg) payload at 19,024 feet during trials at Umling La, Ladakh.⁵³ Operation Sindoor saw the use of Alpha Design's SkyStriker (locally produced through partnership with Elbit Systems of Israel)⁵⁴ and Solar Industries' Nagastra loitering munitions in combat.⁵⁵ Battle-worthiness of Indian drones in all possible environments is well established. Recently, an AI-powered MALE UAV, Kaala Bhairav, developed by a Bengaluru-based company, has bagged an order worth US\$ 30 million from an unnamed South Asian country.⁵⁶ The same drone has also won an international innovation award in Croatia in November 2025.⁵⁷ Both the contract and the award serve as a critical validation of the platform on the international stage, positioning India as an emerging exporter of advanced drone technology.

Dual-use Technology

Drones are a dual-use technology with major use cases in the civilian field, including agriculture, delivery, inspections and monitoring along infrastructure projects and forests. Currently, the global drone market is substantially based on demand in the defence and security domain. However, propelled by innovative uses in other sectors, same is likely to be reduced to around 25 per cent by 2030 (Figure 1).⁵⁸ Thus, it is evident that due to the

dual-use nature of drones, innovations in one field will have second-order benefits in others too.

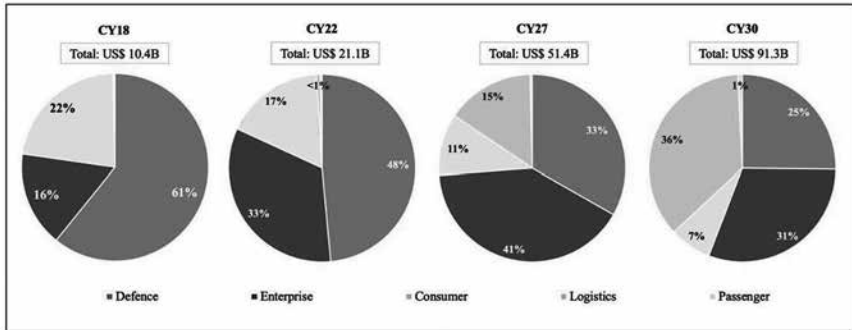


Figure 1 Sector-wise Projection of Drone Usage

Source: Drone Industry Report 2023.

Note: CY: calendar year; B: billion.

Track Record for Meeting Targets

While it appears that the drone industry has got what it takes to deliver and the government is charged up to elevate the local drone ecosystem to world leader status, our track record in trail-blazing endeavours speaks otherwise. In 2019, India’s R&D expenditure was 0.7 per cent of its gross domestic product (GDP) and amounted to 2.8 per cent of global R&D share. Economic Advisory Council (EAC) selected a target of doubling the R&D expense to reach 2 per cent of GDP by 2022 and cover 50 per cent of the global R&D market.⁵⁹ However, India’s R&D expenditure for FY 2020–21 was still just 0.64 per cent of the GDP (developed countries spend 2 per cent, while Israel and Republic of Korea spend around 6 per cent). Further, out of the 7,888 R&D institutions in the country, 66 per cent were in the private sector; but the overall share of private sector in national R&D was under 40 per cent, which had remained unchanged for the past five years.⁶⁰

Such grossly underachieved targets question the projections made by exalted institutions, like the EAC, as well as cast doubt on the efficacy of our national innovation ecosystem. These numbers reflect the dichotomies of our national innovation ecosystem which has jumped to 38th position in the Global Innovation Index (GII) 2025 from earlier 81st position in 2015.⁶¹ Not surprisingly, India’s global share in research publications has increased from 3.1 per cent in 2010 to 5.1 per cent in 2020; and India was ranked seventh in resident patent filing activity globally.⁶² Does this suggest that

growth of India's innovation ecosystem is only in theory (research papers and patents) with very less traction in practice? Does the Indian drone ecosystem have a similar prognosis?

The drone ecosystem of India, having partially delivered thus far, has the potential for breakthrough. However, past success does not guarantee attainment of our national objective of becoming a global drone hub in near future. The Indian drone ecosystem needs to embark on a sustained overdrive of innovation in design, applications and process, for realising its objective of domination in the drone sector.

THE WAY AHEAD

There is a need for nurturing a culture of innovative experimentation and risk taking, which can be encouraged through supportive policies, accessible funding and an enabling business environment. The famous *jugaad* or frugal necessity-based innovation must be replaced by high-tech impactful R&D. Though the Indian drone ecosystem has indeed matured over the years and is catching up as the cornerstone of India's innovation environment, implementation of certain key measures will go a long way in its consolidation and growth.

Increase Demand

The indigenous drone market needs a boost in terms of increased demand, which will further spur manufacturing and component ecosystem. Use of drones as a service can also be leveraged for the same. With lower cost of operations and increased time efficiency while using drones, the government as well as private sector must find new use cases to ensure a wide field for drone operations. The use of drones must be made compulsory in transformational projects and smart city plans. In addition, although the export of India-manufactured drones for civilian use has been encouraged by the liberalised policy of 2023, the same must be further promoted by reducing restrictive regulations.⁶³ Few such restrictions are: exclusion of drones with range greater than 25 km and payload more than 25 kg; exclusion of software exports even for small civilian drones; and complicated permissions for demonstrations abroad.

Ownership by Defence Forces

Since maximum share of the drone market is generated by the defence sector, the services have to take a lead by simplifying procurement processes and

ensuring proliferation of drones. The drone industry will deliver what is demanded. Hence, innovative drone products must be brainstormed and supported through various design and development schemes. Apart from what may be required today, some thought must be given to the trajectory of drone innovations in near future, thereby showing interest in novel and revolutionary products and use cases. Another major aspect for encouraging global levels is increasing the numbers ordered by the defence forces. Fewer numbers do not provide incentives and economic viability, which is required for private industry to sustain.⁶⁴ The capital budget may be increased for procurement of drones since money spent on drones will ultimately get invested back in the drone ecosystem (multiplier effect). Demand for innovations in technology and design concepts has to be driven by the user, else we will be constrained to fight tomorrow's war with today's drones.

Encourage Collaboration

We need to move ahead from forming clusters to Centres of Excellence (CoEs) with focus on scale, maturity and specialisation. Thus, collaborative facilities, like DeepDive Labs, for cybersecurity testing, material science and specialised propulsion systems, as well as facilities for component-level certification and international harmonisation standards, are likely to spur innovation-conducive environment.⁶⁵ These may be based on geographic proximity of industries, research institutions and testing facilities, and can be made outcome-oriented by shifting focus from simply providing training and basic testing to delivering measurable industry growth, technological standardisation and integrated commercial deployment. Outcomes must identify Key Performance Indicators (KPIs) that align with national goals, such as the PLI scheme and the push for BVLOS operations. This requires breaking existing silos. One workable solution is building on the Development-cum-Production Partner (DcPP) model of the DRDO, wherein projects are co-developed using more than one private industry, along with embedded academia from centres of higher learning at relevant CoEs.

Increase R&D

We need to increase our spending on R&D. The R&D must be focused on global-level innovations, which will act as a catalyst to demand and potential use cases. Industry must be wary of being content with developing components and products driven by commercial interests only. The drone industry must also invest in difficult and ground-breaking ideas, apart from manufacturing what is achievable today. In this regard, lead must be taken

by established players in the drone ecosystem. In India, the R&D spent by defence and aerospace sector is 1.2 per cent, which is significantly lower than the global average of 3.4 per cent.⁶⁶ A study of top 1,000 listed companies in India found that eight companies were from defence and aerospace industry and these top companies only spend 7 per cent of their turnover on R&D.⁶⁷

After setting a national vision and taking very positive initiatives, the government must hold the industry accountable in this regard. A few initiatives for inducing accountability are: creating a framework for measuring tangible innovation output; mandatory R&D benchmarking and competitions; establishing an independent body, possibly under Anusandhan National Research Foundation (ANRF), to audit R&D claims based on scientific and technological verification; and mandatory disclosure of R&D investment/personnel and infrastructure in annual reports.

Joint Ventures (JVs)

Collaboration with foreign original equipment manufacturers (OEMs) must also be encouraged so as to align the indigenous industry with global endeavours. The recent JV between Adani Defence and Aerospace (India) and Elbit Systems of Israel for manufacturing Hermes 900 MALE UAV is a welcome step, but it is only licensed production and does not comprise transfer of cutting-edge drone technology, like complex aerodynamics and avionics. The only entity in India to attempt development of MALE-class UAVs till date is the DRDO, which, as mentioned earlier, has only been partly successful.⁶⁸ For HALE-class UAVs, India is fully dependent on foreign OEMs. These failures do not imply an end to India's efforts for home-grown solutions, but only highlight the challenges involved in catching up with advanced nations. While efforts for spiral development with the DRDO may continue, inability to develop indigenous solutions should not lead to denial of much-needed capabilities to our defence services. Thus, collaborations and JVs for co-development and co-production (as against only licensed assembly) are likely to be instrumental in India developing its own HALE-class UAVs.⁶⁹

Skill and Human Resource Development

The higher learning institutions and universities need to upscale so as to propel meaningful research and innovation. Metrics, like number of research papers and patents, must be weighed against successful prototyping and proof of concept. Shift must be made from number of patents filed to the actual commercial value of contracts based on intellectual property rights. Collaborative funding between these skill development hubs and industries

must be established with reverse absorption of the graduates on passing out into the drone industry. For instance, the ‘Seven Sons of National Defence’ are a group of seven universities in China deeply rooted in defence industry. They are among the best-funded universities, with almost half of their PhD scholars joining the defence industries. Already, a third of their employees are graduates of these seven universities.⁷⁰ India can adapt this concept by establishing a structured, funded and accountable institutional framework to harness its centres of higher learning, like the IITs and the Indian Institute of Science (IISc), directly for national security and strategic technology development. It may also include: directed research funding through the ANRF, jointly overseen by the MoD and the Department of Science and Technology; mandatory internship and recruitment with the DRDO and Public Sector Undertakings; and clear intellectual property and security protocols.

Flight Testing Infrastructure

India needs to work on creation of permanently designated, fully instrumented national drone corridors that can handle a high volume of complex, cross-city BVLOS traffic. The transition from experimental exemption to routine commercial operation is the elusive need of the hour, requiring focus on certified detect and avoid technology, mature UTM and dedicated airspace corridors encouraging urban air mobility solutions at scale. The US has seven Federal Aviation Authority (FAA)-nominated drone flight testing sites, which were carefully selected out of 25 proposals from 24 states based on varied factors, like geography, climate, UAV research needs, airspace use and experience. Each site has a unique charter and consists of vast volume of coordinated, dedicated or authorised airspace, often covering thousands of square miles, that can be accessed for testing.⁷¹ These primarily focus on airspace R&D and integration across massive, designated geographical volumes, leveraging a mature aviation ecosystem, unlike the Indian testing sites which mainly focus on type certification and component testing as of now.⁷²

Increase Local Component Manufacture

More than 75 per cent of drone components, including critical ones, like motors, autopilot, power pack, payloads and sensors, are imported, while only low-tech components, like airframe and cables, are produced indigenously (Figure 2). The main imports are from China, Taiwan and the US.⁷³ However, many defence companies are resorting to ‘white-labelling’

(importing items and putting ‘Made in India’ label).⁷⁴ Some mechanism has to be evolved to ascertain the IC in the drones manufactured by India. Merely accepting vendor certification or calculating the IC based on the cost of parts must be done away with. Possible alternatives, like auditing the production process, validating technical documentation, calculating the domestic value addition, auditing bill of material and verifying source code and firmware, must be evolved. The industry, along with industry associations—like the Drone Federation India (DFI), the Society of Indian Defence Manufacturers (SIDM), and the Federation of Indian Chambers of Commerce and Industry (FICCI)—could be tasked to work out viable alternatives. The recent ‘Bharat Drone Stack Conference 2025’, organised by the DFI, was a featured thematic discussion that dissected gaps in India’s current drone value chain. It saw active participation by leading policymakers, industry experts, component manufacturers and innovators to shape the future of India’s drone ecosystem. Such initiatives need to be further encouraged.⁷⁵

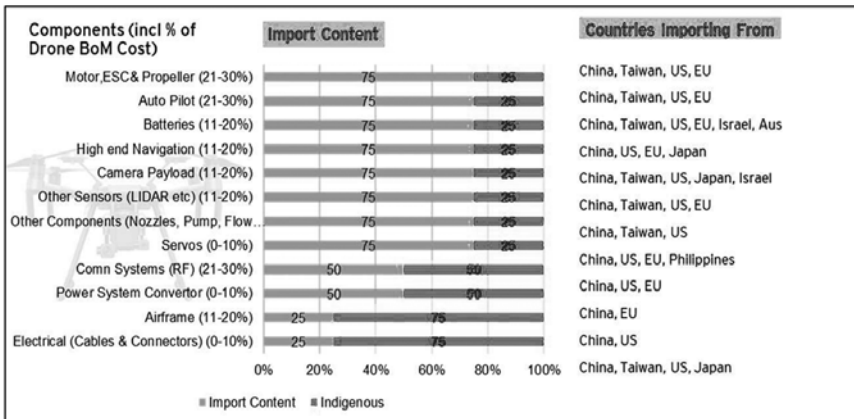


Figure 2 Indigenisation Content of Indian Drones

Source: ‘Making India the Drone Hub of the World’, FICCI and EY, August 2022.

Choosing Innovation Over Business as Usual

It is often said that innovation can create winners, but it also creates losers as new technology replaces old. This, many a time, causes resistance to change from existing established players.⁷⁶ It is imperative that this change is encouraged. In fact, established industry members must drive and invest in this change through innovative R&D, apart from their efforts to capture the current market. An expert on China, Tai Ming Cheung, argues in his book

that what fuels China's rise is that its interests of national security, economic development and innovation converge.⁷⁷ Thus, for the Indian drone ecosystem to grow, all stakeholders need to converge their efforts, rather than take seemingly disjointed steps mainly driven by individual entities. India needs to invest in the full stack of drones domain, rather than being restricted to manufacturing conventional drone products. Innovation is a combined responsibility and it is the key to global domination.

CONCLUSION

The future of India's drone ecosystem is projected for explosive, policy-driven growth, aiming to position the nation as a global drone hub by 2030. The market is expected to surge to between US\$ 4.8 billion and US\$ 23 billion in manufacturing potential by the end of the decade, largely driven by defence and agriculture.⁷⁸ Liberalised regulations (Drone Rules, 2021) and the PLI scheme are successfully boosting indigenous manufacturing. The next critical phase involves finalising BVLOS regulations and scaling-up UTM to enable high-volume logistics, infrastructure monitoring and large-scale agricultural services. Challenges remain in localising the component supply chain and accelerating R&D to maintain global competitiveness.

Serious and effective steps must be taken for stringent implementation of the import ban, while continuing parallel efforts to indigenise core components and technologies. Investments and R&D must focus on establishing India not only as the greatest 'prosumer' of drone products but also as a leader in drone technology ecosystem globally. Industry must diversify market concentration from defence and agriculture to global consumer/recreational and niche innovative applications.

We need a strategic shift in our approach to innovation and research because if we continue doing what we have done so far, we will only get what we already have got till now! In order to churn out world-class innovative drones, we require the drone industry to take the lions share in R&D; the government to demand greater accountability while continuing positive policy push; academia to enhance collaboration for meaningful and path-breaking research leading to tangible benefits; enhanced contribution from industry bodies; and continuous demand for better innovative services and products by the defence forces and other users. Only then can the Indian drone ecosystem unlock this immense societal and economic potential of the skies, become a dominant player and realise the national vision of being the global drone hub by 2030.

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