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No. 87 September 2024

Military - Civil Technology Fusion (MCTF)

For Making India Atmanirbhar Global Drone Hub@2030

Rajiv Kumar Narang

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ABBREVIATIONS

AAM	-	Advanced Air Mobility
ADB	-	Army Design Bureau
ADE	-	Aeronautical Development Establishment
AFRL	-	Airforce Research Laboratory
AI	-	Artificial Intelligence
ALFA	-	Air Launched Flexible Assets
ALH	-	Advanced Light Helicopter
AMCA	-	Advanced Medium Combat Aircraft
AMSL	-	Above Mean Sea Level
AR	-	Augmented Reality
ASTE	-	Aircraft Systems and Testing Establishment
ATOL	-	Automatic Take Off and Landing
BIS	-	Bureau of Indian Standards
BHUMI	-	BSF High-Tech Undertaking for Maximising Innovation
BVLOS	-	Beyond Visual Line of Sight
CAPF	-	Central Armed Police Forces
CATS	-	Combat Aerial Teaming Systems
CATS (MAX)	-	Combat Aerial Teaming Systems (Mothership for Air Teaming)
CB	-	Certification Bodies

CEMILAC	-	Centre for Military Airworthiness & Certification
CFEES	-	Centre for Fire Explosive and Environment Safety
CMI	-	Civil-Military Fusion
CeE	-	Centres of Excellence
CSIR-NAL	-	Council of Scientific and Industrial Research-National Aerospace Laboratory
CTIB	-	Commercial Technology and Industrial Base
CUAS	-	Certification Scheme for Unmanned Aerial Systems
CVRDE	-	Combat Vehicle Research and Development Establishment
C&QA	-	Certification and Quality Assurance
D&D	-	Design and Development
DAD	-	Directorate of Aerospace Design
DAP	-	Defence Acquisition Procedure
DcPP	-	Development cum Production Partnership
DDPMAS	-	Design, Development and Production of Military Air Systems and Airborne Stores
DEAL	-	Defence Electronics Application Laboratory
DGCA	-	Directorate General of Civil Aviation
DIO	-	Defence Innovation Organisation
DLI	-	Design Linked Incentive
DMA	-	Department of Military Affairs
DND	-	Directorate of Naval Design
DoD	-	Department of Defence

DPSU	-	Defence Public Sector Undertakings
DPUP	-	Development Production and User Partnership
DRDO	-	Defence Research and Development Organisation
DST	-	Department of Science and Technology
DTIB	-	Defence Technology and Industrial Base
DTIS	-	Defence Testing Infrastructure Scheme
EASA	-	European Union Aviation Safety Agency
EDD	-	Equipment Development Department
EEL	-	Economic Explosives Ltd
EO/ IR	-	Electro-Optic / Infra-Red
FAA	-	Federal Aviation Authority
FADEC	-	Full Authority Digital Engine Control
GCS	-	Ground Control System
GeM	-	Government e-Marketplace
GFR	-	Government Financial Regulations
GTRE	-	Gas Turbine Research Establishment
HAL	-	Hindustan Aeronautics Limited
HALE	-	High-Altitude Long-Endurance
HAPS	-	High-Altitude Pseudo Satellites
HF-24	-	Hindustan Fighter-24
HQ IDS	-	Headquarters Integrated Defence Staff
IA	-	Indian Army
IAF	-	India Air Force

IAI	-	Israeli Airspace Industries
IC	-	Indigenous Content
IC	-	Internal Combustion
IDDM	-	Indigenously Designed, Developed and Manufactured
IIT Kanpur	-	Indian Institute of Technology Kanpur
IMAP	-	Indian Military Airworthiness Procedures
IN	-	Indian Navy
LAM	-	Loitering Aerial Munitions
LCRA	-	Light Canard Research Aircraft
LD	-	Logistics Drone
LD (HA)	-	Logistics Drone (High Altitude)
LEO	-	Low Earth Orbit
MALE	-	Medium-Altitude Long-Endurance
MCF	-	Military-Civil Fusion
MCTF	-	Military-Civil Technology Fusion
MeitY	-	Ministry of Electronics and Information Technology
MHA	-	Ministry of Home Affairs
MoCA	-	Ministry of Civil Aviation
MOQ	-	Minimum Order Quantity
ML	-	Machine Learning
MoD	-	Ministry of Defence
MoU	-	Memorandum of Understanding
MP-IDSA	-	Manohar Parrikar Institute for Defence Studies and Analyse

MREO	-	Medium Range Electro Optic
MSME	-	Micro, Small and Medium Enterprises
MUM-T	-	Man-Unmanned Teaming
NAL	-	National Aerospace Laboratories
NIIO	-	Naval Innovation and Indigenisation Organisation
NM-ICPS	-	National Mission on Interdisciplinary Cyber-Physical Systems
NPNT	-	No Permission and No Take Off
NSRT	-	New Space Research and Technologies
NTIB	-	National Technology and Industrial Base
ONR	-	Office of Naval Research
OEM	-	Original Equipment Manufacturer
PLA	-	Peoples' Liberation Army
PLI	-	Production Linked Incentive
PSA	-	Principal Scientific Advisor
QCI	-	Quality Council of India
QR	-	Qualitative Requirements
R&D	-	Research and Development
RFP	-	Request for Proposal
RPA	-	Remotely Piloted Aircraft
RPTO	-	Remote Pilot Training Organisations
RUAV	-	Rotary Unmanned Aerial Vehicle
SAAW	-	Smart Anti-Airfield Weapon
SAR	-	Synthetic Aperture Radar

SBAS	-	Space Based Augmentation System
SDI	-	Software Development Institute
SPV	-	Special Purpose Vehicle
SRUAV	-	Short Range Unmanned Aerial Vehicle
S&T	-	Science and Technology
TASL	-	Tata Advanced Systems Limited
TDF	-	Technology Development Fund
TIDCO	-	Tamil Nadu Industrial Development Corporation Limited
TIH	-	Technology Innovation Hubs
ToT	-	Transfer of Technology
UAM	-	Urban Air Mobility
UAS	-	Unmanned Aerial Systems
UAV	-	Unmanned Aerial Vehicle
UCAV	-	Unmanned Combat Aerial Vehicles
USA	-	United States of America
UTM	-	Unmanned Traffic Management
VR	-	Virtual Reality
VRDE	-	Vehicle Research and Development Establishment
VTOL	-	Vertical Take-Off and landing

Vernacular Words/Phrases

Abhikalp	-	Design
Abhinav	-	Innovate
Anusandhan	-	Research
Atmanirbhar	-	Self-reliant
Atmanirbhar Bharat@2030	-	Self-reliant India by 2030
Atmanirbharta	-	Self-reliance
Anusandhan se Atmanirbhar	-	Self-reliance through research
Protsaahan	-	Incentive
Viksit	-	Developed
Viksit Bharat	-	Developed India
Viksit Bharat@2047	-	Developed India by 2047
Yojana	-	Scheme

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18. Tandem Wing Low Altitude Long Endurance Tactical UAV, Cinguarity Aerospace

18A. Jet Engine High Speed Target Drone, Cingularity Aeropspace

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Executive Summary

The Indian drone industry led by startups and Micro Small and Medium Enterprises (MSMEs) is at the cross roads. It has the potential to outperform other sectors and transform into an innovation and Intellectual Property (IP)-led high-technology high- value industry. However, policy, technology development and ecosystem gaps, and lack of fusion between civil and defence UAV manufacturing industries are major impediments in India's goal of becoming an *atmanirbhar* (Self-reliant) global drone hub by 2030.

The policy reforms in the civil drone sector comprising the civil drone rules-2021; Kisan Drone Scheme, Namo Drone Didi, Production-Linked Incentive (PLI), etc. provided initial impetus for its proliferation. Its employment in the *Svamitva* scheme, agriculture, medical surveys, and other sectors had a significant impact on its expeditious adoption since 2021. However, the absence of a nodal ministry for drone technology, lack of a drone *atmanirbharta* policy, Research and Development (R&D) structures and import dependence on critical components, are barriers to India's global drone hub mission. The absence of initiatives for the development and validation of emerging drone technologies such as remote tracking, detect and avoid systems, Unmanned Traffic Management (UTM), Urban Air Mobility (UAM) etc., are immediate challenges in the integration of drones into the Indian airspace.

In the defence UAV sector, Innovation for Defence Excellence (iDEX), Mehar Baba Competition and other initiatives have stimulated indigenous development of logistics supply, loitering, ISR and swarm small UAVs by the private sector. However, Indian UAV manufacturers remain dependent on import of critical components. The flight trials of *Nishant, Panchi, Rustom-1, Tapas,* Stealth Wing Flying Testbed (SWIFT) and the display of the mock Combat Air Teaming System (CATS), demonstrated the capability of Indian public sector entities to design and develop large Unmanned Aerial Vehicles (UAVs). These UAVs have several indigenous sub-systems; however, induction of large UAVs into service has been a challenge. These challenges need examination and corrective measures instituted to overcome them.

The Civil Military Integration (CMI) and Military Civil Fusion (MCF) policies of the US and China respectively, have been stimulators of growth and competitiveness of their aviation and defence industries. India needs a MCF or CMI policy to transform its promising drone manufacturing industry to be globally competitive. The Ministry of Defence (MoD) promulgated several Indian industry-friendly policies such as positive indigenisation lists, procurement of Indigenously Designed, Developed and Manufactured (IDDM) drones, Innovation for Defence Excellence (iDEX), Mehar Baba Competition, Make-1 in Defence Acquisition Procedures (DAP) and Defence Testing Infrastructure Scheme (DTIS). The absence of similar policies and structures for civil drone technology development in the Ministry of Civil Aviation (MoCA) and other ministries is a hindrance in military and civil technology fusion (MCTF). The MCTF in drones is needed to facilitate optimum utilization of resources, bring coherence in drone technology development and support *atmanirbharta*. Some of the key recommendations that emerge from these deliberations are:

(a) Formulate policy and structures for MCTF, establish a nodal Ministry for UAV Technologies, launch a National UAV Technology Mission and introduce other measures to bring synergy among stakeholders, ministries and other entities, and formulate Indian civil-military UAV manufacturing standards;

(b) Formulate '*Atmanirbharta* in Civil Drones' and 'Indigenously Designed Developed Certification (IDDC)' policies, and launch a 'Design Linked Incentive (DLI)' Scheme. Also, establish Civil drone R&D structures, testing sites, and technology development initiatives.

(c) Create R&D structures in defence forces, reform defence UAV development programmes, formulate 'Indigenous Content (IC) certification' and 'archiving of indigenous design' policies, introduce a Development Production and User Partnership (DPU) Scheme, and enhance public-private and private-private partnerships.

India's transformation into a global drone hub would require deep introspection to identify challenges and instituting course corrections. This Monograph examines the progress of and challenges for India's civil and military UAVs manufacturing industries and proposes measures to overcome them. The proposed military-MCTF in drones can transform India into an *Anusandhan se Atmanirbhar* (self-reliance through research) global drone technology hub@2030.

Chapter 1

Introduction

Drones have been the focus area for the Indian government over the last three years. India has set for itself the goal of becoming the global drone hub by 2030.[1] In addition, it aims to become self-reliant (*atmanirbhar*) in critical technologies and a developed nation by 2047 (*Viksit Bharat*@2047). The Ministry of Civil Aviation or any other entity has not yet defined the tenets of a global drone hub@2030. The trajectory of global aviation and drone technology development indicates that India becoming a global drone hub@2030, would require building a technology and innovation-led high-technology high-value civil-military drone industry in which India is self-reliant in critical technologies as well as a global leader in certain niche drone technologies. The Indian drone industry would need to evolve through R&D, pro-active development and adoption of emerging and innovative drone technologies through trials, formulation of standards and certification mechanisms, articulation of guidelines for standardization and developing enabling technologies for integration of drones in Indian airspace. This would require a transformation in the Indian civil drone technology development trajectory and civil-military fusion.

Drones are also known as UAVs, Unmanned Aerial Systems (UAS) and Remotely Piloted Aircraft (RPA). The terms drones and UAVs are used interchangeably in the Monograph, with 'drone' being a preferred term for the civil variants.

The Indian UAV industry is broadly divided into two segments: civil UAV industry and defence UAV industry, and both are in critical phases

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1 "Government of India has undertaken a series of reforms to make India a global drone hub by 2030", Ministry of Civil Aviation, PIB, 20 April 2022 at https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1818424 (Accessed on 14 June 2024).

of development. Indian civil and military UAV industries have made significant progress in design, development and manufacturing of new and innovative small UAV systems and sub-systems. However, they face ownership, policy, ecosystem and MCF challenges

In the civil UAV manufacturing industry, India continues to import critical components such as semi-conductors, motors, actuators, communication systems, data links, data storage, Ground Control Stations (GCS), magnets, software, miniaturised sensors, payloads, etc. The import of critical systems has created vulnerabilities and unwarranted dependencies. This could put constraints on scaling up production and competing at the global level.

The Indian MoCA unlike the US Federal Aviation Authority (FAA) and the European Union Aviation Safety Agency (EASA) does not take lead in developing civil UAV and enabling technologies to facilitate integration of drones into Indian airspace. The civil UAV technology development ecosystems comprising R&D initiatives, testing facilities, standards formulation and standardization, creates challenges in indigenous development and certification of innovative UAV technologies and their export in the global market.

In the defence UAV industry, India private industry has developed a number of small and innovative UAVs for logistic supply, Intelligence Surveillance and Reconnaissance (ISR) and armed strike roles. Indian public sector entities are developing large drones; however, they have struggled to transform their prototypes into operational UAVs due to various reasons. The *Nishant* tactical UAV development project closed after induction of only four UAVs. The wheeled variant of *Nishant*, the *Panchi* UAV development project, was closed after the flight demonstration of its prototype. The *Rustom-1* or Short Range Unmanned Aerial Vehicle (SRUAV), a TB-2 class of drone, is built on a proven manned aircraft and engine, with a number of indigenous technologies, and yet its future remains uncertain.

The *Tapas* Medium Altitude Long Endurance (MELE) UAV development project was downgraded from a mission mode project to a lower priority DRDO project in early 2024. However, the IAF and the Indian Navy placed orders for six and four *Tapas* surveillance UAVs respectively in June 2024, which provided a much-needed lease of life to this programme[2] These orders provide an opportunity to *Tapas* designers to make necessary design improvements to meet operational requirements. The procurement orders for *Tapas* need to be leveraged to expedite development of the armed *Archer-NG* MALE UAV.

The challenges and course corrections needed to make the indigenous *Rustom-1* and *Tapas* MALE UAV development programmes a success need greater deliberations. The funding, approvals and timelines of High-Altitude Long Endurance (HALE), Unmanned Combat Aerial Vehicles (UCAV), Combat Aerial Teaming Systems (CATS) and futuristic unmanned technologies need to be finalised.

India's unwarranted dependence on import of critical systems, materials, sensors and payloads despite civil and military UAV development initiatives needs introspection. The factors leading to lack of fusion or synergy between India's civil and military UAV technology development trajectories leading to duplications and sub-optimal utilisation of capabilities of each other require special attention.

The indigenous development of swarm, loitering, surveillance, logistics supply, High Altitude Long Endurance, Manned-Unmanned Teaming (MUMT) systems, Medium Altitude Long Endurance (MALE) and other UAVs by the Indian public and private industry despite their challenges indicates that India has the potential and capability to become a leader in drone technology. The Monograph attempts to test two hypothesis:

(a) The Indian drone industry led by startups and MSMEs, has the potential to outperform other sectors and transform into an innovation and IP-led high-tech and high value industry of India.

(b) The fusion between civil and defence drone industries, nomination of a nodal ministry, formation of an *atmanirbharta* policy, creation

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2 Swapna Nair, "Why do the Indian Air Force and navy want to Buy Home-Grown 10 *Tapas* Drones?" *Sputnik India*, 24 June 2024 at https://sputniknews.in/20240624/why-do-the-indian-air-force-and-navy-want-to-buy-home-grown-10-tapas-drones-7696705.html (Accessed on 8 July 2024).

of R&D structures and an enabling ecosystem and self-reliance in critical technologies are essential for India becoming the global drone hub@2030.

In order to trace the trajectory and focus on the challenges of Indian drone industry, a day-long Roundtable was held on the theme "*Atmanirbharta* in UAVs@2030' at the Manohar Parrikar Institute for Defence Studies and Analyses (MP-IDSA) on 3 May 2024. Stakeholders from DRDO, Hindustan Aeronautics Limited (HAL), defence forces, academia, industry, think tanks, scholars and subject experts participated in the Roundtable. Issues to understand the progress and challenges to potential solutions were deliberated upon. In addition, this study has examined primary electronics records of various ministries and government bodies, seeking inputs from domain experts, industry, academia, media reports and other sources. The trajectory and challenges of Indian civil and military UAV industries have been placed under four broad categories:

1. Policy Initiatives and Challenges
2. Drone Technology Development Initiatives and Challenges
3. Drone Development Ecosystem and
4. Military-Civil Technology Fusion (MCTF)

Taking the above into consideration, the Monograph deliberates on the following:

(a) Indian Civil Drone Industry comprising Civil Drone Policy Initiatives and Challenges, Civil Drone Development Challenges and Civil Drone Development Ecosystem Challenges.

(b) Indian defence UAV industry comprising defence UAV policy initiatives and challenges, defence UAV development by public sector units and challenges, defence UAV development by the private sector and challenges, and defence UAV development ecosystem challenges.

(c) MCTF and the government approach in development of UAV technology

The Monograph delves into these issues to understand the progress and challenges of Indian civil and military UAV industries before proposing a way forward that comprises MCTF in UAVs, reforms in the Indian civil drone sector and course corrections in the Indian defence UAV sector.

Chapter 2

INDIAN CIVIL DRONE INDUSTRY

The evolution of the Indian civil drone industry can be attributed to a few visionary leaders in the Defence Research and Development Organisation (DRDO), who ventured to collaborate and transfer drone technology to the Indian start-up ideaForge, led by four college students. The startup was established in 2007 and the appearance of their drone in the film "Three Idiots" placed them in the limelight.[3] They inspired many Indian startups to enter an unexplored domain of drones that was challenging due to an unfavourable policy and technology development ecosystem. They were developing the technology of the future in which no major Indian company was willing to invest.

India banned the operation of civilian drones in 2014[4] due to concerns about their misuse by anti-national elements (ANEs), terrorists and criminals. Indian security agencies raised concerns about the potential risks and challenges of managing the unchecked proliferation of drones. Indian innovators and manufacturers continued to innovate and develop drones and deployed them for varied commercial applications such as surveys, agriculture, medical supplies, etc. They advocated development of technological solutions out of which digital sky and No Permission and No Take Off (NPNT) technologies were suggested and demonstrated.

The development of digital sky, a single-window system for all the information and approvals related to civil drones[5], has been a slow

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[3] Ankit Mehta, CEO, ideaForge in his address in an event titled Innovate X at Mumbai on 26 April 2024.

[4] "Civilian drones banned in India: Report", IndiaToday.in, 13 October 2014 at https://www.indiatoday.in/technology/news/story/civilian-drones-banned-in-india-report-222975-2014-10-13 (Accessed on 3 July 2024).

[5] "Digital Sky, Director General of Civil Aviation" at https://digitalsky.dgca.gov.in/home (Accessed on 3 July 2024).

process while integration of NPNT or a similar solution to track civil drones has not taken off due to the absence of R&D mechanism in the MoCA and the Directorate General of Civil Aviation (DGCA). There were feeble and reluctant attempts to formulate a regulatory framework in India due to lack of consensus among security agencies and stakeholders for allowing operation of civil drones in India. The aspiring Indian drone industry led by innovators, indigenous manufacturers and technocrats developing innovative applications, repeatedly demanded easing of regulations to enable it to grow.

Civil Drone Policy Initiatives

The outbreak of the COVID-19 in India in early 2020, gave an opportunity to the Indian drone industry to demonstrate their capability. The Indian drone industry supported the central government, state governments, security agencies and police in surveillance and related applications.

Drone Rules 2021

The MoCA, Ministry of Home Affairs (MHA), Ministry of Defence (MoD) and other stakeholders after intense deliberations promulgated the UAS Rules-2021 in April 2021, which had some progressive as well as stringent regulatory clauses. Indian industry raised concerns about restrictive and punitive provisions in the rules. The concerns of young Indian drone entrepreneurs were referred to MoCA and other ministries for review. The UAS Rules-2021 were replaced with industry-friendly Drone Rules 2021 on 25 August 2021.[6]

The Indian government did not take shortcuts in the process and yet the process was completed in just four months. The MoCA, with lateral

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6 The Drone Rules, 2021, Ministry of Civil Aviation, 25 August 2021 at https://public-prd-dgca.s3.ap-south-1.amazonaws.com/InventoryList/headerblock/drones/Drone%20Rules%202021.pdf (Accessed on 21 June 2024).

entry Joint Secretary[7] in charge of drones, engaged with industry, academia, users and other ministries to facilitate expeditious promulgation of the Drone Rules-2021.

Other Policy Initiatives

The hope and expectation of creating a high-technology, high-value drone industry of India, motivated the Indian government to launch several policy initiatives that included the Productivity Linked Incentive (PLI)[8], *Kisan* Drone[9], and NAMO *Drone Didi*[10] schemes, the Remote Pilot Training Organisation (RPTO) Scheme[11], the Certification Scheme for Unmanned Aerial Systems (CUAS)[12], the National UTM System[13]

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7 Shri Amber Dubey, Joint Secretary, Ministry of Civil Aviation recruited from the Industry through a lateral entry scheme to bring industry experience in the governance, Rajya Sabha Unstarred Question No. 1081, dated 10.02.2022, https://pqars.nic.in/annex/256/AU1081.pdf, Accessed on 16 September 2024

8 "Production Linked Incentive (PLI) Scheme for drones and Drone Components in India", Ministry of Civil Aviation, 30 September 2021 at https://egazette.gov.in/WriteReadData/2021/230076.pdf (Accessed on 21 June 2024).

9 "Funds for Kisan Drones", PIB Delhi, Ministry of Agriculture & Farmers Welfare, 21 March 2023 at https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1909215 (Accessed on 24 June 2024).

10 "NAMO Drone Didi Scheme is helping women to become integral stakeholders of their local farming supply chains: PM", Prime Minister's Office, PIB, New Delhi, 11 December 2023 at https://pib.gov.in/PressReleasePage.aspx?PRID=1985070 (Accessed on 24 June 2024).

11 "Authorisation of Remote Pilot Training Organisation", Office of The Director General of Civil Aviation, Drone Training Circular 01 of 2022, 15 Feb 2022 at https://digitalsky.dgca.gov.in/assets/files/DTC-1-of-2022-RPTO-Authorisation.pdf (Accessed on 24 June 2024).

12 "Certification of Unmanned Aerial Systems", Ministry of Civil Aviation, 26 January 2022, at https://egazette.gov.in/WriteReadData/2022/232917.pdf (Accessed on 8 June 2024).

13 "National Unmanned Traffic Management (UTM) System# Policy Framework", 24 October 2021, Ministry of Civil Aviation at https://www.civilaviation.gov.in/sites/default/files/migration/National-UTM-Policy-Framework-2021_24_Oct_2021.pdf (Accessed on 8 June 2024).

Policy Framework in October 2021, and the Drone Export in 2023,[14] among others. Most importantly, the Indian government outlined its vision of making India a global drone hub by 2030.

Civil Drone Policy Challenges

The above civil drone policy initiatives taken since 25 August 2021 led to rapid proliferation of drones in India. The civil drones were adopted in agriculture, mapping, medical, logistics supply, mine surveys and other commercial applications. The authorisation of the drone flying training schools, drone training and drone certification mechanisms were operationalised. The ease of import of components facilitated expeditious drone manufacturing on the one hand, while on the other, it created unwarranted dependencies and vulnerabilities. Despite contributing to rapid adoption, the civil drone policy initiatives had certain challenges, some of which are deliberated upon below.

Lack of Drone Technology Validation Mechanism

Drone technology development is expensive and Indian innovators need initiatives from the Government to validate their technologies to operationalise and adopt these technologies. However, the absence of technology development and validation initiatives by the MoCA/ Director General of Civil Aviation (DGCA) becomes a limitation in further development, refinement and adoption of indigenously developed technologies in India.

Absence of Drone Technician Certification Policy

India needs a large number of qualified technicians to enhance acceptability of quality of manufacturing of drones in the global market and needs a policy on certification of drone technicians. The policy on certification of aviation technicians for the manned aircraft formulated

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[14] "Amendment in Category 5B of Appendix-3(SCOMET Items) to Appendix-2 of ITC (HS) Classification of Export and Import Items, Notification Number 14/ 2023", 23 June 2023 at https://content.dgft.gov.in/Website/dgftprod/24ea669e-2e1a-4f53-b9d3-20f0dc1f60a6/Notification%20No.%2014%20English.pdf (Accessed on 21 June 2024).

by DGCA is unfavourable for creating a large pool of skilled technicians in India. The educational requirements for becoming aviation technicians are higher than what is followed globally, which makes skilled labour expensive, reduces its availability while making Indian aviation manufacturing expensive. The certification mechanism for drone technicians should not become a hindrance in the growth of Indian drone industry.

India lacks skilled aviation and drone technicians, while a large number of highly skilled aviation and drone technicians trained by Indian defence forces remain under-utilised as most do not opt for civil certification, which is cumbersome, and expensive due to the requirement of higher qualification. The relevant policies of India, the US and Europe, and challenges of aviation technician certification in India have been deliberated in the research paper titled "Reform in Indian Aviation/ Drone Technician Certification Policy", published in October 2023.[15]

The current informal practice of training of technicians by Indian drone companies that are predominantly developing drones less than 500 Kg, can continue. It would be prudent however, to issue guidelines for drone technicians to standardise maintenance and quality assurance practices. There is a need to formulate a certification policy for drone technicians for development of drones heavier than 500 Kg as they would be employed for transportation of logistics stores and human being within and in between the cities in the near future.

Need for Design-Linked Incentive (DLI) Scheme for Drones

The PLI Scheme was meant to stimulate manufacturing of drone and drone components, encouraging manufacturing of drones.[16] However,

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15 *Reforms in Indian Aviation/ Drone Technician Certification Policy*, Issue Brief, Manohar Parrikar Institute for Defence Studies and Analysis, 31 October 2023 at https://www.idsa.in/issuebrief/indian-aviation-drone-technician-certification-policy-rknarang-311023 (Accessed on 6 June 2024).

16 "Production Linked Incentives (PLI) Schemes for Drones and Drone Components in India", Ministry of Civil Aviation, 30 September 2021 at https://egazette.gov.in/WriteReadData/2021/230076.pdf (Accessed on 8 June 2024).

Indian companies continue to import electronics components, communication and navigation systems, certain types of motors, battery cells, magnets, other critical components, sensors, payloads, and use imported software that have inherent vulnerabilities and unwarranted dependencies, imposing constraints on scaling up production and competing at the global level.

The promulgation of Production Linked Incentive (PLI) scheme and easing of restrictions on import of drone components[17] intended stimulating manufacturing of drones, even if it required using imported drones. It has achieved its initially purpose; rather, it is being misused by some Indian drone traders, who assemble drones with imported components with little indigenous content. The drone assemblers obtain PLI benefits and supply assembled drones to the Indian government. There is a need to review this policy, as easy availability of imported drone components and monopoly of foreign suppliers, including from our neighbouring countries is creating security and scalability challenges. The use of imported critical components needs to be checked. There is a need to introduce design incentives in India to support indigenous development.

Lack of Indigenous Design Certification of Civil UAVs

Indigenous drone and drone component developers face unfair competition from fellow Indian companies who assemble drones with imported components and obtain the airworthiness certification from the DGCA/Quality Council of India (QCI). The companies assembling drones face no risks and they have the financial strength to go for low profit tendering while indigenous developers have to buy machines, create a manufacturing ecosystem, hire design engineers, undergo design

17 "Notification of ITC (HS), 2022 - Schedule-1 (Import Policy), Notification No. 54/ 2015-2020 Dated 9 February 2022. Department of Commerce, Director General of Foreign Trade, Ministry of Commerce & Industry" at https://www.civilaviation.gov.in/sites/default/files/migration/Drone_Import_Policy_9_Feb_2022.pdf (Accessed on 21 June 2024).

changes, undertake testing and trials. All these require funds and make indigenous design and development an economically challenging option for them.

The DGCA issues the airworthiness certificate through QCI, which in turn has delegated the process of validation of testing of civil UAVs to Certification Bodies (CBs). The airworthiness certification of civil drones by DGCA is the certification of its airworthiness and not of the design certification of UAVs, designed by the Indian company.[18] The airworthiness certification is the validation of its claimed performance parameters like its maximum speed, payload carrying capability, endurance and confirmation that UAV is safe to undertake air operations.

The design certification on the other hand, refers to certification of a drone or a drone component that is designed by the Indian entity. India does not have a policy, mechanism, standards and designated agency to issue indigenously designed certificates for the drones and drone components designed and developed by Indian entities. This is a challenge for Indian developers to prove the genuineness of indigenously designed drones to users.

Gaps in Civil Drone Certification Policy

The certification of civil drones is undertaken as per the CUAS.[19] However, the CUAS policy does not have provisions for certification of civil drones weighing more than 500 kg. In addition, the DGCA does not certify UAV components, software, sensors, payloads, etc. as there is no policy, procedures and standards for their certification.

18 Observations of DGCA representatives at Roundtable on Atmanirbharta in UAVs@2030 at Manohar Parrikar Institute for Defence Studies and Analysis, 3 May 2024.

19 "Certification of Unmanned Aerial Systems", Ministry of Civil Aviation, 26 January 2022, at https://egazette.gov.in/WriteReadData/2022/232917.pdf (Accessed on 8 June 2024).

Certification Challenges of Innovative Drone Batteries

The Bureau of Indian Standards (BIS) certifies the drone batteries; however, BIS' primary focus is on certification of Nickel and Lithium-based batteries. There is reluctance to undertake certification of batteries based on emerging and diverse technologies, such as Graphene, Sodium and Aluminium-based batteries, as some of these are being developed indigenously by Indian companies.[20] The certification of such batteries would require creation of testing standards, processes and policies, which is a laborious process. There is reluctance to deviate from existing practices and do that extra work to formulate an ecosystem for certification of new batteries. A similar reluctance is seen in the validation of technologies such as remote tracking, UTM, detect and avoid system and others that are being developed by Indian entities and innovators. The certification of drones and drone components based on trials and testing in emerging, new and niche technologies needs to be adopted, to support innovations by the Indian industry.

Lack of Incentives in Procurement of IDDM UAVs

Indian UAV and UAV components manufacturers also need policy on preferential procurement of Indigenously Designed, Developed and Manufactured (IDDM) UAVs and UAV components to support *atmanirbharta* and scaling-up manufacturing to compete at global levels.

Civil Drone Development Initiatives and Challenges

The Department of Science and Technology (DST), Ministry of Electronics and Information Technology (MeitY) and other entities of the government have taken a number of initiatives, launched drone innovation schemes and established incubation centres. The Government of India established the National Mission on Interdisciplinary Cyber-

[20] Dr Saurabh Markandeya, Kaja Shah, Dreamfly Innovations, Bengaluru Karnataka, in an interaction with the author on 3 May 2024.

Physical Systems (NM-ICPS) with an outlay of Rs. 3660 crores for the next five years. It has established 25 Technology Innovation Hubs (TIHs) in reputed institutions across the country in advanced technologies like Artificial Intelligence (AI)/ Machine Learning (ML), Augmented Reality (AR) / Virtual Reality (VR), Robotics, Cyber security, autonomous systems, etc.

Each TIH has four major activities: 1) Technology Development, 2) Entrepreneurship Development, 3) Human Resource Development and 4) International Collaboration.[21] One TIH, i.e. TiHAN Foundation at IIT Hyderabad is working on "Autonomous Navigation and Data Acquisition Systems (UAVs, etc.). Out of these four activities, technology development and international collaboration has not focused on bridging the technology and capability gaps in the Indian drone and aeronautics industry.

In the drone segment, several incubation centres, Centres of Excellence (CoEs), Drone Technology Parks[22] have been established in academic institutions to support innovators and startups in technology development.

Civil Drone Development

The development of civil drones did not take place in a formal and systematic manner in India, as there were no dedicated drone development initiatives. The pragmatic initiatives launched by the Indian government – Make in India, Atmanirbhar Bharat, Start-ups India and other initiatives, did provide a much needed incentive to Indian innovators; however, these initiatives were not focused on addressing specific technology gaps in the civil drone sector. Some of the innovations and drone development in India took place because of individual initiatives and their ingenuity, and in some cases, without the

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21 "National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS)", Ministry of Science and Technology, Department of Science and Technology, Government of India at https://www.nmicps.in/ (Accessed on 1 July 2024).

22 "Drone Technology Parks, Technology Innovation Hub at IIT Delhi" at https://www.ihfc.co.in/drone-technology-park/ (Accessed on 8 June 2024).

support of government schemes. As a result, it remained a disorganised activity. (Repettion, hence deleted) The funding mechanisms and incentives contributed to the development of drones for commercial applications. The emphasis of these drone development initiatives predominantly focused on manufacturing of structures, software development and integration of various systems acquired from commercial markets. Some of the critical gaps in civil drone technology and in technologies that are needed for integration of drones in the Indian airspace, are yet to be addressed.

Civil Drone Components Development and Challenges

The promulgation of Drone Rules-2021, PLI; and the call for Make in India and *Atmanirbharta* by the Indian leadership, inspired some Indian starts-ups and MSMs to indigenously design and develop drone components in India, The details of some of these drone component developers and manufacturers are given at Appendix "A".

The indigenous content in hardware can be ascertained through physical inspection; however, ascertaining indigenous content in software requires significant technical expertise. In addition, software itself can have many layers and some of it can be developed by using open source basic software. The open source software itself can have limitations and vulnerabilities. The person assessing Indigenous Content (IC) needs to be qualified to validate these assertions. In government organisations, the person involved in acquisition, or the user, may not be technically qualified or may not be mandated to assess indigenous content. As a result, there is hardly any focus on ascertaining indigenous drone components, sensors and payloads.

The airworthiness certification of civil drones is undertaken by the DGCA through QCI; however, QCI and DGCA do not validate or certify indigenous design of the drone. The drone airworthiness certification by DGCA is the only mechanism in India, and the lack of a mechanism for certification of indigenous design of drone components and IC deprives Indian drone component manufacturers of the credibility and incentives to manufacture drone components. Also, procurement procedures do not have a mechanism for incentivising indigenous drone component manufacturers.

The lack of drone component certification has been a major challenge for Indian drone component manufacturers. There are challenges in certification of drones due to lack of a trial-based certification mechanism in the certification bodies. The competition is with those drones that are equipped with innovative technologies such as new propulsion technologies. Users find it challenging to identify Indian drone component manufacturers due to the lack of mapping of Indian drone component manufacturers. There is a need for a mechanism to certify and grade drone component manufacturers, to build confidence among users, about the authenticity of Indigenously-designed UAV components.

India has made significant strides in manufacturing civil drones; however, its companies remain dependent on import for critical technologies, systems, sub-systems and components that could hinder scaling-up production or competing at the global level. Drone technology development could face challenges due to the absence of the corresponding technology development initiatives. Several technologies proposed in the drone policies are yet to be operationalised, in the absence of technology ownership, technology development initiatives and validation mechanisms. There has been little progress in developing enabling technologies needed for integration of civil drones in Indian airspace.

The gaps in India's indigenous UAV technology development trajectory were examined in the research paper titled '*Anusandhan*-led *Atmanirbhar* UAS Industry in India' in 2022. India remains dependent on import of critical components of drones that include GCS, magnets, software, data links, data storage, communication systems, actuators and semi-conductors. These have inherent vulnerabilities and unwarranted dependencies. The import dependencies adversely affect the scaling-up of drone production.[23] In the last two years, newer challenges have

[23] " '*Anusandhan*' led '*Atmanirbhar*' UAS Industry in India", *Journal of Defence Studies*, 16 (4), October-December 2022 at https://www.idsa.in/jds/16_4_2022-anusandhan-led-atmanirbhar-uas-industry-in-india (Accessed on 6 June 2024).

been observed and some of these technology development challenges are deliberated on in the succeeding sections.

Gaps in Civil Drone Technology Development Initiatives of DST

The technology development initiatives are focused on funding academic institutions, start-ups, incubation centres, CoE and others. It was expected that India would become a drone manufacturing hub[24] and the technology gaps would be systematically reduced. However, this did not achieve desired results. These initiatives need to be oriented towards filling the civil drone technology gaps.

Lack of Civil UTM and Enabling Technologies

A civil UTM is needed to detect, identify and track operation of drones especially small, slow and low-flying drones that are difficult to detect with existing air traffic systems. The operationalisation of UTM would depend on a realtime tracking system, a detect-and-avoid system, a reliable communication system and a ground network. The civil UTM should be inter-operable with other civil and military UTMs.

India has not yet developed a civil UTM. The non-availability of civil UTM could become a limitation in expanding the envelop of commercial drones including their operation in Beyond Visual Line of Sight (BVLOS) ranges. These technologies are needed for safe operation of large number of drones, expanding the operating envelop and facilitating collaboration of drones and manned aircraft.

The development of UTM is essential for safe operation of UAVs with high level of automation, collaborative operation with manned aircraft as well as integration in Indian airspace. Indian start-up Navifly Aerospace Technologies Private Limited led by Yashodhan Naik had developed a UTM prototype with funding from Airbus and the Irish

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[24] "Drone Manufacturing Hub, Unstarred Question No 2202, Rajya Sabha, 21 December 2023", at https://sansad.in/getFile/annex/262/AU2202.pdf?source=pqars (Accessed on 8 June 2024).

Aviation Authority.[25] Navifly struggled to convince stakeholders to support further development and adoption of UTM in India, and was acquired by Skye Air Mobility Private Limited, India in 2022. Skye Air launched an indigenous UTM in February 2023, which needed validation and optimisation for operationalisation.[26] However, there has been no progress since then. The operationalisation of indigenous civil UTM would require launching of development and validation initiatives by the MoCA or DGCA,

Focus of Collaborations with Global Partners

The technology collaboration with global partners is another area that needs special attention. The scope and extent of India's technological collaborations with global partners has not narrowed down to critical technology gaps. The ownership of Indian entities, timelines of technology development, and outcomes of collaborations with global partners have not been articulated. The areas, modalities and scope for technology collaboration with global partners remains ambiguous. These initiatives have not resulted in technology outcomes on the ground in most cases. There is a need to review and re-orient such technology development initiatives and schemes The collaboration with global partners needs to be focused on specific technology gaps with articulation of outcomes, earmarking of funding, nomination of technology development partners and laying down of timelines for specific outcomes.

Role of Industry Bodies

The role of industry bodies in *Atmanirbharta* and integration of drones has been ambiguous and inconsistent. The industry bodies are often pro-active in seeking easing of trade policies but are slow in contributing

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25 Yashodhan Naik, at https://www.linkedin.com/posts/yashodhannaik_drones-utm-semiconductors-activity-7186955689108344832-bMJF/ (Accessed on 17 September 2024).

26 Abhijit Bhaskar, "Skye Air launches India's first traffic management system for drones", *Mint*, 7 February 2021 at https://www.livemint.com/technology/tech-news/skye-air-launches-india-s-first-traffic-management-system-for-drones-11675770331263.html, (Accessed on 17 September 2024).

to technology development and validation initiatives. This has been one of the major limitations in development of enabling drone technologies and integration of drones in India. Some Indian private sector entities have developed enabling technologies such as No Permission, No Take Off (NPNT), detect and avoid systems, UAV Traffic Management (UTM) system, etc. However, rules for induction of these enabling systems have not been finalised and their induction has been kept in abeyance. Indian private sector companies and industry bodies, in general, have not been pro-active in the validation and operationalisation of enabling technologies and regulations to facilitate integration of drones in Indian airspace.

Investment in R&D by Private Sector

The R&D funding by the large Indian private companies has been significantly less than their global peers. The indigenous development of larger drones would require greater investment in R&D. Most big Indian private sector companies except Tata Advanced Systems Limited (TASL) have not yet invested in indigenous development of large drones. The assembling and manufacturing of defence products with limited Transfer of Technology (ToT) has been a preferred choice for Indian companies.

The big Indian companies normally lack in-house R&D ecosystems to develop new and niche technologies, which is evident due to their low investments in in-house R&D and lack of innovative products developed by them for the global market. The overall investment by big Indian companies has been limited and there is a scope for improvement. The lack of investment by Indian companies is also because there is lack of certainty about the procurement of indigenously developed products. A study by Prof Pankaj Jalota indicated that investment by large Indian software companies is less than 1 per cent as compared to 15 per cent by Microsoft.[27] The investment of Indian

[27] Pankaj Jalote, "Research Investments in Large Indian Software Companies" at https://www.iiitd.edu.in/~jalote/docs/ResearchInITcosLarge.pdf (Accessed on 22 June 2024).

technology companies on R&D is normally below 5 per cent while investment of leading global technology companies on R&D varies from 15 to 20 per cent.

The requirement of funding for indigenous design and development of large UAVs necessitates investment by big Indian companies. Indian private companies need to increase their investment in R&D to create Intellectual Property Rights (IPR) and compete in the global market.[28]

Handholding by Big Indian Companies

Indian start-ups and MSMEs have been developing niche and innovative drone technologies. They need handholding, guidance and funding to scale-up manufacturing or make inroads in the global market. Most of their funding comes from from foreign investors. Often, they obtain funding though Indian Venture Capital companies, that act as intermediaries for foreign investors as their Indian partners.

The global companies and investors have benefitted more from Indian start-ups and MSMEs than big Indian companies. The global companies identify Indian talent, acquire them, gain a majority stake, shift their operations to other countries to acquire IPRs or gain technology ownership. The big global technology companies benefit more by investing in Indian starts-ups and MSMEs due to a better understanding of innovations, R&D and the technology development trajectory and challenges, leading to benefits in the long-run.

The partnership of big Indian companies with Indian starts-ups and MSMEs has been limited. Companies like Reliance, Adani, Tata and others, have acquired or collaborated with a few Indian UAV start-ups; however, they have not yet been able to take indigenously developed UAVs into global markets.

Most Indian big technology companies have traditionally focused on Transfer of Technology (ToT), license manufacturing and production of sub-systems, for global OEMs. They primarily focus on production,

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[28] "Samvad, Interview with Dr. Samir V. Kamath", Sansad TV, 4 June 2024 at https://www.youtube.com/watch?v=eoJv00pumT4 (Accessed on 8 June 2024).

process optimisation and design improvements, rather than creation of disruptive and globally competitive technologies. Their emphasis on manufacturing and Return on Investment (ROI) in relatively short timelines is an impediment in the technology development in the end.

These companies need to change their approach by increasing investment in R&D, promoting good UAV start-ups and MSMEs and hand holding them to become global players. The big Indian companies can play an important role in ensuring that Intellectual Property Rights (IPRs) remain in India and a high-technology high-value drone industry is developed here. They need to take ownership of drone technology to make a meaningful contribution in India's *atmanirbhar* global drone hub mission.

Civil Drone Development Ecosystem and Challenges

The DST[29] and MeitY[30] have created a civil UAV technology development ecosystem comprising the CoE, and have funded academia and start-ups through industry incubators. The details of some of the policies on drone ecosystems, establishing of CoE and funding of start-ups and MSMEs through industry incubators, are as follows.

1. Maharashtra Drone Mission[31]
2. Tamil Nadu UAV Corporation[32]

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[29] "Brief Statement of Activities 2023-24, Department of Science and Technology", at https://dst.gov.in/sites/default/files/Brief%20Statement%20of%20Activity%202023-24%20English.pdf (Accessed on 22 June 2024).

[30] *Annual Report 2022-23*, Ministry of Electronics and Information Technology (MeitY), at https://www.meity.gov.in/writereaddata/files/AR_2022-23_English_24-04-23.pdf (Accessed on 22 June 2024).

[31] "Maharastra Drone Mission, Indian Institute of Technology, Bombay, October 2023" at https://dte.maharashtra.gov.in/wp-content/uploads/2023/12/Maharashtra_Drone_Mission_Proposal_IITB-24-Oct-23.pdf, (Accessed on 24 June 2024).

[32] "Tamil Nadu Unmanned Aerial Vehicles Corporation" at https://tnuavcorp.com/ (Accessed on 24 June 2024).

3. Drone Tech Centre, Punjab University[33]
4. West Bengal Technology Promotion Guidelines[34]
5. CoE / Research (incl Drone Technologies) - IIT Bombay[35]
6. Drone Technology Park/ Technology Innovation Hub of IIT Delhi[36]
7. Biologically Inspired Robots & Drones (BIRD)/ IIT Delhi[37]
8. CoE in Drones/ Dehradun Institute of Technology University[38]
9. CoE on Drone/ UAV Technology & AI, IIT Guwahati[39]
10. CoE - Drone Technology at IITRAM Ahmedabad[40]

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33 "Drone Tech Centre launches operations at Panjab University", Punjab University, 10 June 2023 at https://iqac.puchd.ac.in/drone-tech-centre-launches-operations-at-panjab-university/ (Accessed on 24 June 2024).

34 *West Bengal Drone Technology Promotion Guidelines*, 2020, Department of Information Technology and Electronics, Government of West Bengal, 28 December 2020 at https://anumati.itewb.gov.in/download/West_Bengal_Drone_Technolgy_Promotion_Guidelines-2020.pdf (Accessed on 24 June 2024).

35 "Centres of Excellence / Research", IIT Bombay at https://acr.iitbombay.org/centres-of-excellence/ (Accessed on 24 June 2024).

36 "Drone Technology Park", Technology Innovation Hub, IIT Delhi (IHFC) at https://www.ihfc.co.in/drone-technology-park/ (Accessed on 24 June 2024).

37 "Biologically Inspired robots and Drones, a Centre of Excellence at IIT Delhi", at https://robotics.iitd.ac.in/BIRD/ (Accessed on 24 June 2024).

38 "DIT University Launches Centre of Excellence in Drone Technologies", DIT University at https://www.dituniversity.edu.in/gallery/254/dit-university-launches-center-of-excellence-in-drone-technology-on-august-25-2023 (Accessed on 24 June 2024).

39 'Centre for Excellence for Drones/ UAV and Artificial Intelligence', IIT Guwahati, 10 November 2021 at https://www.iitg.ac.in/iitg_press_details?p=26/gen-v-k-singh-rtd-hon-ble-mos-for-civil-aviation-&lang=hindi (Accessed on 24 June 2024).

40 "Drone Technology Institute of Infrastructure, Technology Management" at https://iitram.ac.in/dt (Accessed on 24 June 2024).

11. CoE - Drone Technology, Hindustan College of Engineering and Technology[41]
12. CoE including on Drone Tech, MeitY[42]
13. M Tech in Unmanned Aerial Systems / IIT Kanpur[43]
14. Aero Club, Centre for Innovation, IIT Madras[44]
15. Rotorcraft and Advanced Flight Technologies, IIT Madras[45]
16. Aerial Robotics, IIT Kharagpur[46]

Civil Drone Ecosystem Challenges

The civil drone development ecosystem comprises R&D programmes, incubation centres, testing facilities, testing space, mechanism for formulation of standards, guidelines for standardisation and other enabling facilities. India's civil drone development ecosystem is at a nascent stage. The policies, CoEs, incubation centres and academia have initiatives for funding of start-ups and innovators, which have provided initial support to them. These initiatives often help them in

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41 "Centre of Excellence (CoE) - Drone Technology", Hindustan College of Engineering and Technology at https://hicet.ac.in/centre-of-excellence-in-drone-technology (Accessed on 24 June 2024).

42 "Domain Specific Centre for Entrepreneurship (CoE) (incl on DroneTech)", Ministry of Electronics & Information Technology, Government of India at https://www.meity.gov.in/domain-specific-centre-entrepreneurship-coe (Accessed on 24 June 2024).

43 "IIT Kanpur now offers MTech in Unmanned Aerial Systems, the first in India", IIT Kanpur, 14 June 2023 at https://imoc.iitk.ac.in/iitk-news-single.php?newsid=NjY=&page=6 (Accessed on 24 June 2024).

44 "Aero Club, Centre for Innovation", IIT Madras at https://imoc.iitk.ac.in/iitk-news-single.php?newsid=NjY=&page=6 (Accessed on 24 June 2024).

45 "Research Highlights, Rotorcraft and Advanced Flight Technologies", IIT Madras at https://raftlab.iitm.ac.in/Research.html (Accessed on 24 June 2024).

46 "Aerial Robotics", IIT Kharagpur at https://arl-kgp.github.io/ (Accessed on 24 June 2024).

developing prototypes of niche and innovative technologies. However, these initiatives are not systematically channeled towards building capabilities and bridging specific and critical technology gaps. The start-ups, after developing prototypes, struggle to refine their products to meet user requirements due to paucity of an enabling ecosystem. Some of the key challenges are deliberated next.

Persistence of Technology Gaps

India continues to remain dependent on imports for magnets, critical materials, electronic components, sensors, payloads, software, etc., despite having the ecosystems and initiatives This ecosystem and initiatives are not focused on developing UAV technologies in which India is lagging and filling the UAV technology gaps in a systematic manner and that is seen in terms of the dependency on import of critical components and sub-systems. The outcomes of these initiatives need to be aligned with the UAV technology gaps in India. These initiatives should lead to *atmanirbharta* in critical UAV technologies.

Absence of R&D and Validation Initiatives

Indian private sector entities have been able to develop small drones with their innovations, as they required low investments and a limited ecosystem. Indian private sector companies are transitioning from developing small multi-copter drones to large fixed wing drones for surveys, logistics supply, UAM, Advanced Air Mobility (AAM) that weigh more than 500 kg. These entities would require civil UAV R&D initiatives by the MoCA or the designated nodal ministry.

The R&D initiatives are needed to pro-actively develop and validate real time tracking, UTM, detect and avoid systems, to stimulate indigenous design, development and manufacturing of large drones and associated technologies for various applications.

Lack of Civil UAV Test Sites and Corridors

The dedicated facilities for testing of large civil fixed wing UAVs are currently not available to Indian civil drone developers. The UAVs being developed for UAM and Advanced Air Mobility (AAM) for intra-city and inter-city connectivity respectively need drone corridors and drone landing sites in and around cities to test and validate these technologies. The indigenously developed civil UAVs including fixed wing UAVs – especially the one requiring testing of their operations up to hundreds of kilometres and altitudes in thousands of feet – need dedicated testing airfields with runways and testing corridors with significant horizontal and vertical airspace. The low-cost easily available test sites and testing corridors are needed to test the full envelop including high-altitude and long-range civil UAV operations.

Accreditation and Availability of Laboratories

The laboratories of the academic institutions, incubation centres and public sector entities lack NABL and other accreditations, which are needed for products developed by civil drone innovators. The availability of these laboratories is often limited due to man power, resource and policy constraints. These laboratories need to obtain and make available the required accreditation 24 hours a day, 7 days a week and 365 days a year, to leverage these national resources.

Lack of Indian Standards for Civil UAVs and Components

India has been a follower of global standards and not an initiator of standards. Indian- manufactured UAVs and UAV components including the ones developed by DPSUs,[47] face challenges in exporting their products in the global market due to the absence of Indian standards. The creation of Indian standards is the need of the hour if India has to take the lead in drone technology and establish itself in the global market. The standards provide a base or a template for the potential buyers to ascertain the quality and reliability of the product. They also provide an assurance that development of such products are systematic and they can depend on the quality, reliability and performance. The

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[47] Air Cmde Muthanna (Retd.), former Test pilot, Light Combat Aircraft (LCA) in an interaction with author in May 2024.

formulation of standards for innovative products requires a pro-active approach in undertaking trials, which is lacking and needs correction.

Standardisation of Civil UAVs and Components

The standardisation helps in scaling-up manufacturing and growth in the industry. The standardisation should be such that it allows innovations and product development while creating standardisation in domains, so that there is interoperability and scaling-up of production as far as possible. Indian companies developing drones / UAVs and associated technologies need a certain level of standardisation in these systems to become economically viable and competitive in the global market.

Archiving of Civil Testing Drone Data

In the civil drone sector, the drones are certified for performance while in most cases, the full envelopof dronesis not being tested and certified. The emerging capabilities of the domestic civil drone industry necessitate certification of new drones, components, sensors and payloads, expansion of operating envelope, trial-based certification of emerging technologies and formulation of Indian standards. All these would require an archived database, which is lacking.

UAV and Aeronautics Technology Education

Education in UAV and aeronautics technology in India is tilted towards publishing research papers rather than translating knowledge into real-life products and technologies. None of the education institutions in India except IIT Kanpur has a runway. The non-availability of enabling facilities becomes a limitation in translating theoretical knowledge into development of niche and innovative drone and aeronautics technologies. The increasing urbanisation around IIT Kanpur would limit the use of its runway for testing and validation of aeronautics and drone technologies in the times to come. IIT Kanpur has started a

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[48] "M. Tech, Masters in Unmanned Aerial Systems (UAS) Engineering", IIT Kanpur at https://www.iitk.ac.in/aero/m-tech-uas, accessed on 8 June 2024.

Masters in Technology (M Tech) in Unmanned Aerial Systems Engineering.[48] MeitY launched a programme for human resource development through capability building in education and training of UAVs.[49] These initiatives provide a beginning in higher education in drone technology, but they fail to address significant gaps in aeronautics and drone education.

'As a whole, the higher education system is not suitable for taking the lead in aeronautics and development of drone technology. There is a need for establishing dedicated aeronautics and drone technology universities with required infrastructure for practical training to plug this critical gap.

Import Dependence and Atmanirbharta

India continues to import flight controllers, electronics components, magnets, battery cells, sensors, payloads, and use imported software despite spending liberally on these initiatives. There is a need to move beyond allocation of funds to make such funding outcome-oriented to fill specific technology gaps in given timelines. The failures should be acceptable but liable to scientific scrutiny, and lack of effort or under-performance should be addressed.

India will witness operation and adoption of UAVs, UAMs and AAMs whether they be Indian or imported. The challenge lies in ensuring that India is self-reliant in the development and manufacturing of new and innovative UAV technologies including UAMs, AAMs and UTMs.

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[49] "Schemes/ Projects", Ministry of Electronics & Information Technology, Government of India at https://www.meity.gov.in/content/schemes-projects (Accessed on 2 July 2024).

Chapter 3

Indian Defence UAV Industry

The development of large defence UAVs is led by the public sector while private companies have developed small but innovative UAVs. Indigenously developed SRUAVs, tactical UAVs and the *Tapas* Medium-Altitude-Long-Endurance (MALE) UAV has been developed by Aeronautical Development Establishment (ADE), a DRDO laboratory, with an order for acquisition of ten *Tapas* UAVs having been placed recently. HAL has initiated development of Combat Air Teaming System (CATS). The National Aerospace Laboratory (NAL), a CSIR laboratory, has initiated the development of High-Altitude Pseudo Satellite (HAPS).

In the private sector, the solar-powered HAPS UAV developed by New Space Research Research and Technologies (NSRT), an Indian private sector company, created a national record of flying 27 hours in early 2024. The small drones developed by startups and MSME have had greater success due to the involvement of users. The Mehar Baba UAS Swarm Competition, iDEX and emergency procurements facilitated their development.

The trajectory and challenges of the Indian defence UAV industry can be divided into three main segments, namely, 1. Defence UAV Policy Initiatives and Challenges, 2. Defence UAV Technology Development Initiatives and Challenges, and 3. Defence UAV Ecosystem and Challenges.

Defence UAV Policy Initiatives

The Indian government has taken several policy initiatives to support indigenous design and development of defence UAVs by the public and private sector. The Make-I, Make-2 and IDDM provisions in the Defence Acquisition Procedure (DAP) were leveraged to develop defence UAVs by the ADE, NAL and other public and private sector entities. In addition, Innovation for defence excellence (iDEX) wasleveraged by the Indian Army, the Indian Air Force and the Indian

Navy to develop a variety of drones and drone applications as well as Intelligence Surveillance and Reconnaissance (ISR), military logistics supply, medical supply and loitering UAVs.

The IAF launched the Mehar Baba Competition in October 2018 to develop the UAV swarm for Humanitarian Assistance and Disaster Relief (HADR). The Mehar Baba Competition stimulated development of niche and innovative swarm UAV technologies for various civil and military applications. Indian companies developed the armed UAV swarm for the military as well as the commercial drone swarm for display and demonstrations. The IAF launched the second edition of Mehar Baba competition in 2022 and its outcome is awaited. In addition, the DRDO leveraged the Technology Development Fund (TDF) to develop enabling drone technologies through the private sector companies and start-ups.

Defence UAV Policy Challenges

The technology development initiatives and IDDM procurement provisions of the DAP empowered public and private sector entities to develop a wide variety of defence UAVs. However, there are still significant gaps in the defence UAV development and procurement policies as well as challenges in their implementation. Indigenous UAV developers face challenges in selling their products due to various reasons. Suppliers who supply UAVs assembled from imported components with negligible indigenous technology exploit the lacunae in procurement policies. Some of the policy challenges are discussed below.

R&D Structures in Defence Forces

The defence forces are important players in the design and development (D&D) of defence technologies including UAVs. The defence forces of the US have R&D structures such as Air Force Research Laboratory (AFRL),[50] Office of Naval Research (ONR),[51] Army Futures

50 "Skyborg", AFRL at https://afresearchlab.com/technology/skyborg (Accessed on 10 June 2024).

51 "Vehicle Research and Subsystems", US Naval Research Laboratory at https://www.nrl.navy.mil/tewd/vrs/ (Accessed on 10 June 2024).

Command, Army Innovation Command and other military research laboratories[52]. The Peoples' Liberation Army (PLA), Navy and Air Force also have similar R&D structures.[53] The R&D verticals and laboratories of defence forces and their personnel as members of design teams play an important role in design and development of defence technologies. However, the structure and role of these institutions, their contribution in technology development and contribution of defence forces personnel as members of design teams, in technology development has not been examined in India.

The Army Design Bureau (ADB),[54] the Directorate of Aerospace Design (DAD) of the Indian Air Force (IAF)[55] the Directorate of Naval Design (DND) and the Naval Innovation and Indigenisation Organisation (NIIO),[56] act as interfaces between the industry and defence forces. They also facilitate in arranging interactions with stakeholders and address industry concerns. However, the ADB, DAD and DND, unlike the defence forces in the USand China, do not have research verticals. In addition, tri-Services defence organisations, i.e. the Directorate of Military Affairs (DMA) and the Headquarters Integrated Defence Staff (HQ IDS) also lack R&D structures to support and where required, take a lead in developing defence technologies.

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52 "DEVCOM", The Army's Foundational Research laboratory at https://arl.devcom.army.mil/ (Accessed on 10 June 2024).

53 Michael S. Chase, et al, "Emerging Trends in China's Development of Unmanned Systems", RAND Corporation, 2015 at https://apps.dtic.mil/sti/tr/pdf/ADA616066.pdf (Accessed on 10 June 2024).

54 "Army Design Bureau", Indian Army at https://indianarmy.nic.in/content2/adb/introduction-adb (Accessed on 8 June 2024).

55 "Directorate of Aerospace Design" at https://www.makeinindiadefence.gov.in/admin/writereaddata/upload/project/project_file/Brief_of_Collbrativr_long_rangr_target_destruction_sysTEM_amended.pdf, and https://techobserver.in/videos/air-commodore-rajiv-mittal-on-digital-for-defence-modernisation-and-indigenisation-271249/ (Accessed on 8 June 2024).

56 "Naval Technology Acquisition Council Meeting", Ministry of Defence, 23 March 2022 at https://pib.gov.in/Pressreleaseshare.aspx?PRID=1808821 (Accessed on 8 June 2024).

Defence Forces Personnel in Design Teams

Indian defence forces personnel do not normally join as members of design teams in development projects unlike the personnel of research laboratories of the US and Chinese Defence forces. The lack of participation of Indian defence forces personnel in the design teams means that they remain outsiders or observers in the design and development projects. Sometimes the deputed personnel do not have the specific technology/design background. Defence forces personnel possessing such qualifications adds significant value to development projects. The MTech and PhD courses can be aligned with technology development projects of Indian defence forces to enhance their contribution.

The involvement of defence forces personnel as members of design teams would not lead to significant increase in manpower as defence forces have already placed their personnel in the Project Monitoring Teams (PMTs) for such projects. The placing of technically qualified defence forces personnel (MTech/PhD) with specialisation in the technology being developed in indigenous projects, can address several limitations and challenges.

The inclusion of technically qualified personnel in design teams would reduce development timelines, as they would be able to prevent design flaws at the concept formulation and design stage itself, instead of at the review stage.

The tenures of Indian defence forces personnel in such projects are currently short, which creates discontinuity. The frequent changes are undesirable in such high technology projects. Reforms are needed in the human resource management policies by Indian defence forces for optimal utilisation of technical manpower to build high technology defence equipment and contribute towards *atmanirbharta*.

Test Pilots and Test Engineers in UAV Development

Retired testing pilots and test engineers can play an important role in the success of indigenous aviation / UAV development programmes. The tactical UAVs developed by DRDO, are yet to be inducted despite indigenous development of several systems, sensors and payloads. The process of acquisition of ten *Tapas* UAVs has been initiated recently. The inability to induct a series of indigenous UAVs comprising *Nishant, Panchi* and *Rustom-1* (SRUAV) developed by Aeronautical Development Establishment (ADE), indicates gaps between the understanding of developers and users. Some of these gaps can be addressed by inducting suitable test pilots and test engineers.

The HAL has benefitted by inducting test pilots; however, DRDO does not have retired test pilots and test engineers from defence services on its rolls. They can guide DRDO about the concept of operations and envisaged requirements of users. This will help in developing products that would meet users' expectations. These personnel are better equipped to explain to users the reasons and advantages of indigenous systems developed by DRDO.

Airworthiness Certification of Defence UAVs

The Centre for Military Airworthiness (CEMILAC) promulgated the Draft Indian Military Airworthiness Bill-2024 on 14 February 2024 with the aim to establish robust guidelines for airworthiness, design, and product conformity of military aviation systems in India. The Bill seeks to streamline certification processes and enforce stringent quality control measures.[57] However, there are concerns and ambiguities in the draft bill that need to be examined and addressed. Some of the key observations are:

1. **Certification Body**–The CEMILAC, a regulatory body under the Department of Defence R&D is vested with the responsibility of airworthiness certification of military aircraft, helicopters, Unmanned Aerial Vehicles (UAS), aero-engines, air-launched weapons and other airborne stores.[58]

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57 "Indian Military Airworthiness Bill, 2024", 14 February 2024 at https://dgaeroqa.gov.in/writereaddata/Portal/Circular/70523_1_1_Revised%20IMAA%20Bill%20Feb%202024_11zon-2.pdf (Accessed on 12 July 2024).

58 Centre for Military Airworthiness (CEMILAC), DRDO at https://www.drdo.gov.in/drdo/cemilac-test (Accessed on 12 July 2024).

2. **Quality Assurance (QA)**–The Director General Aeronautical Quality Assurance (DGAQA) is an organisation under the Department of Defence Production (DDP), Ministry of Defence (MoD). It is the regulatory authority for Quality Assurance (QA) and final acceptance of military aircraft, aero engines, airborne systems, avionics, armament, allied ground systems.[59] The QA has three elements comprising:

    1. Design QA,
    2. Manufacturing QA and
    3. User QA.

    1. The design QA currently being undertaken by the CEMILAC, production entities have their own QAs and DGAQA provides user QA since there is no aerospace QA body in the IAF (users).[60]

3. **Independence and Autonomy–**There are concerns that placing CEMILAC under DoD R&D and QA bodies under the DDP, MoD, could bring in subjectivity in certification and quality assurance. The CEMILAC and DGAQA, due to their affiliations with DRDO and DDP MoD, respectively may also influence their independence and autonomy.

4. **Third-Party Certification**–Robust and transparent provisions are needed for third-party certification to reduce CEMILAC's and DGAQA's workload and meet the growing demand of private companies. In addition, third-party certification is being followed in many leading aviation-manufacturing countries.

5. **Design Organisation Approval of Start ups/MSMEs–** There is a need for creating design organisation approval mechanisms

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59 "Directorate General of Aeronautical Quality Assurance (DGAQA)", DDP, MoD at https://dgaeroqa.gov.in/ (Accessed on 12 July 2024).

60 Shri Hari Babu Srivastava, former Distinguished Scientist and Director General Technology Management of DRDO in an interaction with the author in June 2024.

for Indian companies, including MSMEs and startups, that are involved in the design and development of aircraft, UAVs, airborne systems, airborne stores, components, sensors, payload, and software. This will reduce the workload of airworthiness and quality assurance bodies and raise the standards of aviation and UAV design and development in India.

6. **Design Organisation Gradation Policy**–The Design Organisation Gradation policy is needed for gradation of Indian companies including MSMEs and start-ups based on their ability to design, develop and maintain quality standards. This will help in identifying the companies having different levels of design and QA capabilities in drones and aeronautics.

IC and Indigenous Design Certification of Military UAVs

The Defence Acquisition Procedure-2020 (DAP-2020) stipulates that Indigenous Designed Developed and Manufactured (IDDM) product with more than 50 per cent Indigenous Content (IC) given preference in procurement. The purpose of this policy was to promote local manufacturing in India by Indian companies. However, 50 per cent of IC was calculated by subtracting the cost of bills of materials from the total cost of sale of the equipment. This provision had an inherent flaw, as assembled products could be supplied as an IDDM product by merely doubling the cost of materials with negligible indigenous content and local manufacturing by Indian companies.

IC Percentage Certification–The MoD decided on 30 November 2023 that in all categories of procurement cases, minimum 50 per cent of indigenous content shall be in the form of material, components and software that are manufactured in India.[61] However,

61 "Defence Acquisition Council approves acquisition proposals worth Rs 2.23 lakh crore to enhance the operational capabilities of the Armed Forces", PIB Ministry of Defence, 30 November 2023 at https://pib.gov.in/PressReleasePage.aspx?PRID=1981135#:~:text=It%20has%20been%20decided%20that,that%20are%20manufactured%20in%20India (Accessed on 3 July 2024).

implementation of the revised policy has created challenges, as there is no entity in India that has the mandate to certify IC percentages of defence equipment based on components, materials and software.

CEMILAC is entrusted with the responsibility of certification of airworthiness of manned and unmanned aviation products.[62] However, it does not have the mandate for certification of indigenously designed aviation products. CEMILAC is the only body that has significant experience of aviation design certification and validation in India. Its experience could be leveraged to build an indigenous design certification body and establish associated mechanisms.

Indigenous Design Certification– In the unmanned domain, CEMILAC has been involved in the certification of *Rustom-1* and *Tapas* UAVs and has gained significant experience of certification of large UAVs and their sub-systems. The Draft 'Indian Military Airworthiness Bill-2024' proposes providing airworthiness certification to aviation platforms; however, there is no provision for according certification to indigenously designed products.[63]

A sample of the weightage criteria for design certification of the UAV or a product could include 50 per cent for indigenous design, 40 per cent for integration capability and 10 per cent for testing and validation capabilities. Within the design criteria, the ability to design critical systems could have higher weightage. This approach could help in developing an enabling ecosystem in India as well as promote indigenous design.[64]

IPR Concerns–Indian companies while seeking Indigenous design certification may have to share details of high-value IP information.

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62 "Centre for Military Airworthiness and Certification (CEMILAC)", Defence Research and Development Organisation (DRDO) at https://www.drdo.gov.in/drdo/cemilac-test (Accessed on 22 June 2024).

63 "Indian Military Airworthiness Bill, 2024" at https://dgaeroqa.gov.in/writereaddata/Portal/Circular/70523_1_1_Revised%20IMAA%20Bill%20Feb%202024_11zon-2.pdf (Accessed on 3 July 2024).

64 Prof A.K. Ghosh, former Professor, Department of Aerospace Engineering at IIT Kanpur and currently with Tata Advanced Systems Limited in an email dated 12 May 2024.

The technology companies are extremely sensitive to sharing IP information. The compromising of IP information can affect the future of a company. Therefore, it is extremely important that robust IP protection mechanisms are in place.

Incentives for Increasing Indigenous Content

Increasing the indigenous content in indigenous development projects undertaken by the public and private sector is desirable; however, there is no incentive to increase the indigenous content, which is a major challenge. Most indigenous development projects undertaken though iDEX, Mehar Baba Competition, Make-1 etc., struggle to increase indigenous content based on indigenously developed sub-systems. Most Indian manufacturers of UAVs prefer to import engines, hydraulic systems, electronics systems, airframes etc. as required, rather than collaborate with fellow Indian companies to increase indigenous content. This is due to the absence of Qualitative Requirements (QRs) seeking maximum indigenous content based on sub-systems, materials, components, software, sensors, payloads, etc. as a mandatory criteria for procurement. This needs correction to reduce vulnerabilities and unwarranted dependencies.

Policy on Archiving Indigenous Defence UAV Designs

In the defence UAV segment there is no formal mechanism to archive designs of defence UAVs and other technologies developed by DRDO laboratories and DPSUs. The need for formulating such a mechanism was discussed during the Roundtable on *Atmanirbharta* in UAS@2030.[65] The archiving of designs of the *Nishant* and *Panchi* UAVs and their analysis by DRDO scientists could have given them useful lessons to institute course corrections in ongoing and future UAV development programmes. The archiving of designs, challenges and learning would

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65 The non-availability of mechanism and mandate to provide Indigenous Design Certification was discussed during the Roundtable on 'Atmanirbharta in UAVs@2030' at the Manohar Parrikar Institute for Defence Studies and Analysis (MP-IDSA) on 3 May 2024.

help the new generation of scientists of DRDO and DPSUs in using the data bank and historical records to draw lessons and use it for improving future design, reducing mistakes, avoiding known challenges and bringing an efficient and progressive approach in design and development.

Spiral Development of UAVs

The *Nishant* and *Panchi* UAVs, despite developing several sub-systems and technologies, were dicontinued and their experience was not adequately utilised to pursue spiral development, upgrades, etc. The Design and Development (D&D) projects are often discontinued after the completion of the prototype or TOT to the production partners. The development of niche technologies is an iterative process like a spiral, where further R&D is needed to achieve higher level of performance, quality, maintenance, upgrades, etc., through design improvements.

No funding is normally allocated for spiral development of products on completion of the development and certification phase. The approval for funding for such projects requires following the full process of project approval as a new project, which is complex and time consuming. In addition, the approval of defence forces is required when seeking funding approval for spiral development of projects. The defence forces after rejecting a prototype resort to import similar products to meet their operational requirements and hence they may not be interested in such projects. This is a limitation in leveraging lessons from operations for further development, upgradation and development of future variants.

It is difficult to match technology and quality standards of products developed by global technology leaders with years of R&D effort in the absence of spiral development programmes for upgrades and future variants. Review of funding for spiral development of projects is essential for developing globally competitive products.

Review of DcPP

The *Tapas* UAV was developed under the Development-cum-Production Partner (DcPP) scheme in which the ADE was the development partner and HAL and Bharat Electronics Limited (BEL) were the Production partners. The DPSU were taken as development partners since no private sector entity joined as a production partner. On the other hand, HAL and BEL despite being the production parters, did not join the Tapas project during the design phase till the milestones were met. This was not a classical DcPP with product partners joining the development team. The design and development phase of the project was with the DRDO with negligible participation of production partner.[66]

The *Tapas* fell short of desired performance levels despite having HAL as the development partner, which has enormous experience of manufacturing a wide variety of foreign aircraft as well as design, development and manufacturing of indigenous aircraft. The inability of *Tapas* to meet user requirements despite having the DcPP arrangement between DRDO and HAL/ BEL, needs to be examined. The gaps in the DcPP policy or its execution should be identified and corrective measures instituted to optimally utilise this policy for effective and timely execution of future UAV development projects.

Non-Availability of Indigenous / iDEX Products Vertical in GeM

There is no mechanism to identify indigenously-designed and developed products in the Government e- Marketplace (GeM), which is the Indian government's online platform to buy various products and equipment for government bodies. The GeM operating under the policies and guidelines of the Ministry of Commerce and Industry,[67] does not have policies on *atmanirbharta*, prioritising procurement of indigenously-designed products and use of indigenously designed products for

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[66] Nabanita R. Krishnan, former Director (ITM), DRDO, Roundtable on 'Atmanirbharta in UAS@2030' at MP-IDSA, 10 July 2024.

[67] Ministry of Commerce and Industry at https://commerce.gov.in/press-releases/national-mission-on-government-e-market-gem-portal/#:~:text=Ministry%20of%20Commerce%20and%20Industry,-DEPARTMENT%20OF%20COMMERCE&text=Achieve%20cashless%2C%20contactless%20and%20paperless,on%20government%20expenditure%20in%20Procurement. (Accessed on 6 June 2024).

various services being sought by the government agencies through this portal. GeM does not have a vertical to display and sell indigenously developed products or products-based services.

The GeM only focuses on transparency and not on supporting indigenously designed and developed products. The absence of such a mechanism makes it difficult for the government bodies to identify and buy indigenously designed and developed drones and drone components. The items developed under the iDEX, Mehar Baba Competition, and Technology Development Fund (TDF), are not listed in GeM, which deprives users in selecting IDDM products developed under these initiatives. Therefore, the policy for the procurement of indigenously developed products from GeM is required for achieving the goals of the *Atmanirbhar* global drone mission.[68]

Procurement of Indigenous UAVs by All Ministries

The policies of all Ministries do not have provisions for preference in the procurement of indigenously designed UAVs. The lack of policy in all ministries on the procurement of indigenous designed UAVs and UAV-based services, the uncertainty of orders for indigenously designed UAVs and inefficiencies in procurement by the government makes indigenously developed UAVs economically unviable.

Below Par Bidding Challenge

There have been instances where bidders quote way below the budgeted value to obtain contracts where the quoted price was unviable since it was less than the cost of procurement of basic materials. Such contracts are often dishonoured or the quality of products or services is degraded. Sometimes, indigenous developers and manufacturers suffer because of low-priced quotes. Indigenous manufactures working on thin margins often do not have the financial wherewithal to continue design, development and manufacturing of UAVs and other systems. This

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68 Government e Marketplace (GeM) at https://gem.gov.in/aboutus (Accessed on 6 June 2024).

discourages indigenous design and development, and encourages assembling or trading of drone technologies. Corrective measures are needed against such flaws of the procurement system to support indigenous design and development.

QRs and Timelines

The unrealistic Qualitative Requirements (QRs) and timelines, synergy among stakeholders and ownership are some of critical factors that need course correction. The QRs must be based on envisaged Concept of Operations and the potential roles in which the UAVs are likely to be deployed. The extremely high operational QRs proposed by users without an understanding of the technology development trajectory and challenges becomes a limitation. Therefore, inclusion of defence forces personnel with technical expertise in the design teams could bridge some of these gaps. The development timelines and failure rate of indigenous UAV development projects can be reduced significantly with the proposed reforms.

User Trials

Indian startups, MSMEs and other companies are often asked to participate in user trials or carry out demonstration of their UAVs and systems by various formations of the Indian Army, Navy, Air Force, and Central Armed Police Forces (CAPFs), which places a financial and resource burden on Indian OEMs, especially startups and MSMEs. This leads to wastage of resources that could be used for product development, design improvements, upgrades, etc.[69] There is a need for formulating a common policy and mechanism that prevents wastage of resources, brings in standardisation in trials and demonstration. A provision could be created for acceptability of trial / demonstration results across the arms and services of the Army, Air Force, Navy and CAPFs.

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69 The issue of repetition of trials by different arms and services of the Army, Navy, Air Force, CAPF and others was deliberated during the Roundtable on 'Atmanirbharta in UAVs@2030' at MP-IDSA on 3 May 2024.

IPR Focus in Global Collaborations

The collaborations and partnerships can expedite manufacturing of civil-military UAV technologies. Some Indian public and private sector companies have collaborated with global OEMs for ToT and local manufacturing. Adani Defence and Aerospace collaborated with the Elbit Systems, Israel to manufacture *Hermes-900* UAVs in India as *Drishti-10*.[70] The manufacturers claimed to have achieved 70 per cent indigenous content in *Drishti-10*; however, there is no clarity on ToT and local manufacturing of critical sub-systems.[71]

The collaborations and joint ventures between Indian public and private sector companies with global partners in most cases have not resulted in the development of niche and innovative technologies and creation of joint Intellectual Property Rights (IPRs). There has been a lack of focus among Indian entities on design upgrades, development of future variants and leveraging the knowledge to develop newer systems on their own.

HAL manufactured more than 600 Russian MiG-21 aircraft and never developed future variants while China went on to develop a variant of MiG-21 named F-7 and its upgrades. The IAF acquired the design of the Avro transport aircraft in 1961 and transferred its design to HAL in 1964. However, HAL did not develop its upgraded variants. Indian private companies have a similar history of license manufacturing and production of defence industrial products.

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70 Kuldeep Negi, "Indian Navy's Adani Defence Made *Drishti-10* UAV Undertakes Maiden Flight", *Swarajya*, 9 February 2024at https://swarajyamag.com/news-brief/indian-navys-adani-defence-made-drishti-10-uav-undertakes-maiden-flight (Accessed on 20 August 2024).

71 "Navy Chief Unveils Firsts Indigenously Manufactured *Drishti-10* UAV of Adani Defence & Aerospace", 10 January 2024 at https://www.adani.com/en/newsroom/media-release/navy-chief-unveils-first-indigenously-manufactured—drishti-10-uav-of-adani-defence-and-aerospace (Accessed on 20 August 2024).

The licence manufacturing or ToT has often led to continued dependence on foreign OEMs for niche manned and unmanned aeronautics technologies. Indian public and private sector companies establishing collaborations and partnerships with global OEMs need to move towards joint development of critical UAV technologies and IPR creation by Indian entities.

Defence UAV Development by Public Sector and Challenges

The focus of the DRDO and public sector companies has been on developing relatively large defence UAVs. Some of the large indigenous defence UAV development projects undertaken by the DRDO, HAL and NAL, their challenges, and future plans are discussed below.

Nishant/ Panchi

Nishant, a vehicle-mounted, rail-launched tactical UAV, was the first UAV that was developed by Aeronautics Development Establishment (ADE), a DRDO laboratory.[72] *Nishant*, equipped with an indigenous engine, had achieved an altitude of 3.72 km against the requirement of 3.66 km.[73] Four *Nishant* UAVs were inducted by the Indian Army in 2011 against the order of sixteen UAVs. All four *Nishant* UAVs had crashed by 2015. However, concerns were expressed that vehicle-mounted *Nishant* could give away its position to satellite surveillance. As a result, a wheeled version of the *Nishant* UAV that named *Panchi* was developed that had first flown in 2014.[74]

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72 "Nishant", Defence Research and development Organisation at https://www.drdo.gov.in/drdo/nishant (Accessed on 10 June 2024).

73 "Rotary Engine for *Nishant* and *Panchi* UAV", Defence Research and Development Organisation at https://www.drdo.gov.in/drdo/rotary-engine-nishant-panchi-uav, (Accessed on 16 February 2024).

74 "Panchi", Defence Research and Development Organisation at https://www.drdo.gov.in/drdo/panchi(Accessed on 10 June 2024).

Fig.1. Nishant UAV, ***Source:*** Kaushal mehta at English Wikipedia, CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons, Accessed on 20 September 2024.

Nishant and *Panchi* had an indigenous 55 horsepower rotary engine, data link, a launcher for *Nishant*, and other subsystems. Both the *Nishant* and *Panchi* UAV development projects were closed in the absence of orders. These two important UAV programmes with significant indigenous sub-systems were closed without a technical analysis of their failures, limitations and challenges, which deprives the country of valuable lessons that could have been taken to prevent mistakes in future programmes.

Rustom-1/ SRUAV[75]

Rustom-1, also known as the Short Range UAV (SRUAV) is a single pusher propeller engine that was developed by converting the Light Canard Research Aircraft (LCRA) into an unmanned version. The SRUAV can fly for 10 hours, has a range of 200 km and can fly up to an altitude of 20,000 feet. Its first successful flight took place in 2010. It is developed from an existing manned aircraft based on a proven airframe and propulsion system and thus fulfills the desired safety and

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75 "*Rustom-1*", Defence Research and Development Organisation at https://www.drdo.gov.in/drdo/rustom-1 (Accessed on 10 June 2024).

reliability parameters. It has undergone several iterations, upgrades and integration of various sensors and systems. It is equipped with the Automatic Take-Off and Landing (ATOL), indigenous communication systems, flight simulator, Ground Control System (GCS), and other systems. The SRUAV was used as a test platform to test and validate various technologies that were being developed for *Tapas*. The armed SRUAV has been equipped with indigenous air-to-ground *HELINA* missiles.[76]

Fig.2. Rustom-1/SRUAV, ADE, courtesy author

The SRUAV is a tactical UAV that is comparable to Turkey's *TB-2*, Pakistan's *Shahpur* and China's CH-3. However, the induction of the SRUAV remains uncertain. The non-induction of SRUAV despite having several indigenous and proven systems, indicates gaps between development and user expectations. The non-induction and absence of technical review and a corresponding programme to modify, upgrade or develop a variant that can meet the requirement of users, is leading to wastage of meagre but valuable resources of the country.

Rustom-II/ Tapas

Tapas Beyond Horizon-201 (*Tapas BH-201*), Medium Altitude Long Endurance (MALE) UAV[77] earlier known as *Rustom-II,* was sanctioned in 2011 as a mission mode project to meet the Intelligence Surveillance

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[76] "India's SRUAV-W Conducting Weapons Trials", *India Defence News*, 16 February 2023 at https://www.indiandefensenews.in/2023/02/indias-sruav-w-conducting-weapons-trials.html (Accessed on 10 June 2024).

[77] "*Tapas BH*", Defence Research and Develoment Organisation at https://www.drdo.gov.in/drdo/tapas-bh (Accessed on 10 June 2024).

Target Acquisition and Reconnaissance (ISTAR) requirement of the Indian defence forces. It flew its first flight in 2016 and achieved a maximum altitude of 28,000 feet and endurance of 18 hours[78] against the requirement of 30,000 feet altitude and 24 hours endurance in 2023. The *Tapas* programme was downgraded from a Mission Mode (MM) project to a Technology Demonstration (TD) project of the DRDO in December 2023. This meant discontinuation of special funding for *Tapas* and that DRDO would have to manage development of *Tapas* from its own limited funding.[79]

Fig.3. Tapas MALE UAV, ADE, courtesy author

The Air Force and Navy took the lead in placing orders for the procurement of six and four *Tapas* UAVs, which came at a critical phase when the viability of the *Tapas* project was being questioned. The support by the Air Force and the Navy could go a long way in the progress of indigenous UAV programmes.

Need for Technical Review of SRUAV and Tapas Projects

India's first two tactical UAV (i.e. *Nishant* and *Panchi*) development projects were discontinued after prototype development and induction

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78 Manjeet Negi, "India to Continue developing capabilities of Indigenous Tapas Drones", *India Today*, 16 January 2024 at https://www.indiatoday.in/india/story/drdo-indigenous-tapas-drones-capabilities-development-trials-navy-arabian-sea-karnataka-2489122-2024-01-16 (Accessed on 10 June 2024).

79 "India shelves biggest project to develop advanced UAV", *The Times of India*, 15 January 2024 at https://timesofindia.indiatimes.com/india/tapas-failed-to-meet-altitude-requirements/articleshow/106844470.cms (Accessed on 6 June 2024).

of only four *Nishant* UAVs. However, neither was there an independent technical review of the *Nishant* and *Panchi* UAVs, nor were the challenges identified. As a result, several indigenously developed technologies such as the indigenous 55 horsepower engine, thde rail launcher and other sub-systems were also lost. The fate of the ongoing *Rustom-1* (SRUAV) programme is also uncertain.

Tapas was a fast paced project with tight timelines. The short timeline of 12 years from its approval in 2011 to down gradation in 2021 for the complex MALE UAV development project was extremely challenging. In addition, the DRDO had to develop a number of subsystems, which required extensive research and development effort in diverse fields. The apprehensions about the success of the project were high considering that *Nishant* and *Panchi* could not meet expectations

Users as Partners and Exit Clause in Tapas – The Air Force, Army and Navy as users provided a project monitoring team comprising test pilots and test engineers. However, their technically qualified personnel did not join the *Tapas* development project as development partners. Users had an exit clause if desired performance or QRs were not achieved. The Indian defence forces as users provided operational requirements and testing support but did not join as partners. The lack of participation of the defence forces as development partners and the provision of the exit clause proved to be one of the limitations of the *Tapas* project.[80]

Tapas is being modified to overcome its limitations. It is important to undertake a technical review of these projects to identify technology gaps and institute corrective measures for their success. The induction of *Tapas* in limited numbers would help in generating operational data and leverage lessons from user experience, for design improvements and development of future variants. This data and experience should be used to modify, improve and upgrade to make it user friendly at the earliest.

80 Nabanita R. Krishnan, former Director (ITM), DRDO, Roundtable on 'Atmanirbharta in UAS@2030' at MP-IDSA, 10 July 2024.

Funding by Users and MoQ – The indigenous design and development of UAVs is expensive. The lack of participation of users deprives incisive operational employability requirements to the design teams during the design phase and makes such projects vulnerable. The lack of funding by users gives them observer status and they have little say in the development phase. This creates apprehensions in the minds of users about the viability and progress of the project. On the other hand, the absence of Minimum Order Quantity (MOQ) also creates uncertainty about the viability of the project.

The inclusion of shared funding by users would enhance their contribution in the indigenous development projects. However, users have limited funding for their acquisitions and some shared funding would need to be allocated to users for such projects. Articulation of MoQ would enhance viability of such projects and provide opportunities for further improvements in indigenously designed UAVs after their induction.

Archer-NG

The DRDO amid challenges of developing *Tapas* and the reluctance of users to accept it, launched another programme to develop the *Archer* Next Generation (*Archer-NG*) MALE Armed / ISTAR UAV. This is a twin boom single engine pusher propeller UAV that is smaller and lighter than the T*apas*. It is expected to carry similar payloads and have higher endurance to meet the user requirements. *Archer-NG* would use several indigenously developed systems to fast track its development.

Fig. 4. Archer-NG MALE UAV, ADE, courtesy author

HALE UAV

India does not have a *HALE* UAV development programme. Tata Advanced Systems Limited (TASL) is developing a jet engine *HALE* UAV;[81] however, there is no official roadmap with development timelines, stakeholders and dedicated funding for indigenous development of the *HALE* UAV. The configuration, stakeholders and concept of operations for the development and employment of *HALE* UAVs are yet to be articulated.[82] The requirement of developing a stealth jet engine *HALE* UAV to increase operating speed, altitude and for enhancing survivability for operation on the northern border, needs to be examined.

UCAV/ RPSA

Remotely Piloted Strike Aircraft (RPSA) also referred to as Unmanned Combat Aerial Vehicle (UCAV) is to be developed by the ADE. The scale model of RPSA, known as Stealth Wing Flying Testbed (SWIFT), flew its maiden test flight on 1 July 2022.[83] The flight test indicated viability of the developing a full-fledged flying wing stealth UAV by Indian designers and engineers. The Operation Requirements (ORs) of the RPSA for air and naval versions have been finalised. The SWIFT is undergoing further testing before the proposal for developing RPAS is finalised by the DRDO. However, the funds for the full-scale UCAV project are yet to be released.

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81 "The race for India's HALE UAV heats up" idrw.org, 31 January 2024 at https://idrw.org/the-race-for-indias-hale-uav-heats-up/#google_vignette (Accessed on 9 June 2024).

82 Anoop Verma, "Defencing India's Bborders and Geopolitical Interests in the Areas of Emerging Defence Ttech", 3 May 2024 at https://government.economictimes.indiatimes.com/news/defence/defending-indias-borders-geopolitical-interests-in-the-age-of-emerging-defence-tech/109790670 (Accessed on 10 June 2024).

83 "Maiden Flight Test: India's Stealth Flying Wing Technology Demonstrator Carried Out Successfully", *Swarajya*, 1 July 2022 at https://swarajyamag.com/news-brief/maiden-flight-test-indias-stealth-flying-wing-technology-demonstrator-carried-out-successfully (Accessed on 8 June 2024).

Fig. 5. Stealth Wing Flying Testbed (SWIFT), ADE, courtesy author

The RPSA could become a stepping-stone to the development of larger stealth long-range unmanned or optionally manned bomber aircraft. The development of long-range bomber would enable India to undertake deep penetration strike missions. The RPSA / UCAV development is being undertake by the DRDO and there is ambiguity on the participation and ownership of users and production partners. The participation of users as development partners would fill the gaps in the development phase and meet the requirement of users. Future variants of RPSA could be developed with capabilities closer to the H-20 stealth bomber being developed by China.[84]

RUAV-200 Helicopter UAV

HAL partnered with DRDO and IIT Kanpur to develop the Rotary Unmanned Aerial Vehicle-200 (RUAV-200). This is a helicopter UAV and its maiden flight is expected to take place in late 2024/ early 2025. The RUAV-200 is expected to have a maximum take-off weight of 200 kg, 3 hours endurance, a maximum range of 400 km, 6000 meters service ceiling and carry a 40 kg payload. It would be equipped with a EO/IR day/night camera and be able to operate in temperatures between -35 to +55 degree celsius.[85] The RUAV-200, is a co-axial rotary

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84 Keiichiro Azura et al, "U.S.Wary of China's next-Generation Stealth Bomber As Development of H-20 Reachers Final Stage", *The Japan Times*, 7 May 2024, at https://japannews.yomiuri.co.jp/politics/defense-security/20240507-184494/ (Accessed on 8 July 2024).

85 Raunak Kunde, "HAL Revs up Production of High Altitude RUAV-200 Drone", IDRW.org, 13 April 2024, at https://idrw.org/hal-revs-up-production-of-high-altitude-ruav-200-drone/#:~:text=The%20RUAV%2D200%2C%20short%20for,effort%20within%20India's%20defence%20sector., (Accessed on 17 September 2024).

wing (helicopter) UAV powered by a 52 Kg liquid fuel engine with a peak output of 30 KW. It is expected to have a maximum speed of100 Mph and maximum range of 400 km.[86]

The Indian Navy issued a Request for Information (RFI) for procurement of 40 Naval Shipborne UAS' on 28 June 2022. These UAVs were needed for surveillance, signal intelligence (SIGINT), target acquisition, reconnaissance and maritime domain awareness. The Navy acquired the Austrian Schiebel Camcopter S-100 helicopter UAVs that would be manufactured by Schiebel Systems India – a subsidiary of the Schiebel Group, the OEM of S-100 and VEM Technologies of India in Hyderabad.[87]

The S-100 can be fitted with gasoline or Kerosene (S1 or S2) engines. It can land on a small helicopter deck of a ship. The engine and gearbox would be supplied by Schiebel from Austria. Schiebel is likely to obtain DGCA certification for its helicopter UAVs to get a foothold in the Indian commercial market.[88] The S-100 has an endurance of 6 hours with a payload of 34 kg, extendable to 10 hours with an external fuel tank. It has a Maximum Take-Off Weight (MTOW) of 200 kg, a maximum speed of 185 kmph and a loiter speed of 102 kmph. It can be fitted with EO/IR, SAR, LIDAR, SIGINT, loudspeaker and spotlight. It can carry a maximum payload of 50 kg[89]

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86 Manish Kumar Jha, "Will HAL's RUAV-200 helicopter drone achieve military-grade capabilities? *Financial Express*, 9 May 2023 at https://www.financialexpress.com/business/defence-will-hals-ruav-200-helicopter-drone-achieve-military-grade-capabilities-3072892/ (Accessed on 6 July 2024).

87 "Indian Navy, Successfully Completes Maiden Pilot and Maintainer Training of the Unmanned Shipborne Aerial System CAMCOPTER S-100", raksha-anirved.com, 28 December 2023 at https://raksha-anirveda.com/indian-navy-completes-camcopter-s-100-training/ (Accessed on 7 July 2024).

88 "S-100 will provide much Needed Flexibility to Sea Based Ops to Indian Navy, Says, Schiebel India CEO Jajati Mohanty", *First Post*, 6 July 2024 at https://www.firstpost.com/india/camcopter-s-100-will-provide-much-needed-flexibility-in-sea-based-ops-to-indian-navy-says-schiebel-india-ceo-jajati-mohanty-13789849.html, (Accessed on 7 July 2024).

89 "Schiebel Camcopter S-100", Schiebel, at https://schiebel.net/products/camcopter-s-100-system-2/ (Accessed on 7 July 2024).

The experience of licence manufacturing indicates that long-term dependence on license manufacturing adversely affects domestic industry. It creates perpetual dependence on foreign OEMs for upgrade and development of future variants. The need for building indigenous helicopter UAVs was highlighted by Dr G. Satheesh Reddy, former Chairman DRDO, during his address at the Roundtable in May 2024.[90] Wg. Cdr. B.S. Nijjar, a helicopter pilot and researcher, in an article in 2018, highlighted the challenges related to the development of RUAV. The joint project between HAL and Israeli Airspace Industries (IAI) to convert the *Chetak* into a shipborne RUAV that was launched in 2006, had not progressed. He had argued that building an unmanned version of the indigenous Advanced Light Helicopter (ALH) would be an ideal HADR platform for the first Mehar Baba Competition. The helicopter UAV is expected to have better performance at high altitude vis-a-vis multi-copter UAVs.[91]

The challenge for HAL would be to make the RUAV-200 helicopter UAV a success at an early date. The requirement of building an armed variant of the RUAV-200 helicopter UAV may also be examined. The Indian private sector has also developed a wide variety of small UAVs and it has the capacity to develop such a platform within India if the need arises.

CATS

HAL started development of the CATS system in the second half of 2018 and it took shape in late 2019 and early 2020. The CATS programme revolves around the twin seat Light Combat Aircraft Mk-

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90 Address by Dr G Satheesh Reddy, former Chairman DRDO and Scientific Advisor to Raksha Mantri, during the Roundtable on 'Atamanirbharta in UAS@2030' at Manohar Parrikar Institute for Defence Studies and Analysis (MP-IDSA), New Delhi on 3 May 2024.

91 Wg Cdr B.S. Nijjar, , "The RUAV & The Mehar Baba Prize", 8 October 2018 at https://capsindia.org/wp-content/uploads/2021/10/CAPS_Infocus_BSN_20.pdf (Accessed on 5 July 2024).

1A that will work as a Mothership for Air Teaming (MAX).[92] The CATS will have the following elements:

1. The CATS (MAX) is expected to carry air-to-air and air-to-ground weapon systems including indigenous Smart Anti-Airfield Weapon (SAAW), a long-range precision-guided standoff munition developed by DRDO.

2. Air-Launched Flexible Assets (ALFA) is a swarm of small weaponised drones. The small drones would be housed in a carrier mounted on CATS MAX. The carrier would be capable of gliding around 100 km before deploying drones to strike enemy targets.[93]

3. *CAT Hunter*, a cruise missile mounted on CATS (MAX)

4. *CATS Warrior*, a twin engine high altitude long endurance armed UAV. The Warrier would act as a loyal wingman drone that could be controlled from CATS MAX, and would complement it in operations. The trials of the full-scale *CATS Warrior* could take place between 2025 and 2026.[94]

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[92] Atul Chandra, "HAL unveils ambitious air-teaming system centred on *Tejas* Flight Global", 4 February 2021 at https://www.flightglobal.com/defence/hal-unveils-ambitious-air-teaming-system-centred-on-tejas/142280.article (Accessed on 5 July 2024).

[93] "Flight Testing of India's 'Loyal Wingman' Warrior Drone to Begin By 2024: Report", 2 April 2022 at https://swarajyamag.com/defence/flight-testing-of-indias-loyal-wingman-warrior-drone-to-begin-by-2024-report (Accessed on 5 July 2024).

[94] "HAL Starts testing Composites for *CATS Warrior* Programme", IDRW.org, 28 April 2024 at https://idrw.org/hal-starts-testing-composites-for-cats-warrior-program/ (Accessed on 5 July 2024).

Fig 6. Warrior Drone Combat Aerial Teaming System (CATS), HAL, courtesy author

CATS Aero-Engine–HAL is has two in-house aero-engine options for the *CATS Warrior*. The upgraded PTAE-7 aero-engine having Full Authority Digital Engine Control (FADEC), which was designed as a power plant for target drones in 1980s.[95] PTAE-7 is a 400-kg, 3.43 kN single spool turbojet engine, that was certified in 2019.[96] The second option, HTFE-25, is a twin-spool mixed flow, low-bypass 25 kN turbofan aero-engine. The high-pressure spool comprises a five-stage high-pressure compressor driven by a single-stage high-pressure turbine while the low-pressure spool consists of a three stage low-pressure fan driven by single-stage low-pressure turbine. The HAL is aiming to certify its engine by 2025.[97]

CATS Data Link–HAL is testing the indigenous data link on BAE Systems Hawk-I trainer aircraft. The secure indigenous datalink is one of the most critical elements of CATS programme, as secure and

[95] Atul Chandra, no. 89.

[96] "PTAE-7, Small Gas Turbine Turbojet Engine", 30 April 2019 at https://www.drdo.gov.in/drdo/sites/default/files/2021-10/TA-1379.PDF (Accessed on 7 July 2024).

[97] "HAL loyal wingman project to go airborne by 2024", *Janes*, 23 March 2022 at https://www.janes.com/osint-insights/defence-news/air/hal-loyal-wingman-project-to-go-airborne-by-2024 (Accessed on 5 July 2024).

effective operation of unmanned assets would largely depend on the data link.[98] HAL is collaborating with start-ups as well; its in-house body, the Aircraft Research and Design Centre is involved in the development of CATS.[99]

High-Altitude Pseudo-Satellite (HAPS)

New Space Research and Technologies (NSRT), a Bengaluru based company, has taken the lead in developing light weight solar-powered HAPS in India. HAPS files higher than the traditional High-Altitude Long-Endurance drones and at lower altitude than the Low-Earth Orbit (LEO) satellites. Indian The Air Force supported the NSRT's journey to HAPS development, when NSRT applied for iDEX's Open Challenge-1.[100] The NSRT demonstrated an endurance of 21 hours in December 2023. The HAPS, if successful, is to be inducted under the Rs 100 crore Make-1 project of the IAF.[101]

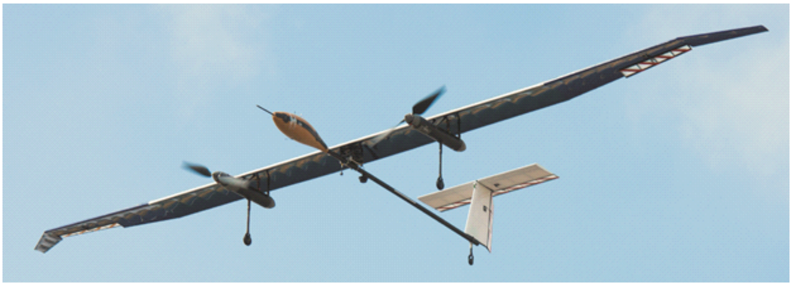

Fig 7. High Altitude Pseudo Satellite (HAPS), New Space Research & Technologies Pvt Ltd (NSRT), courtesy NSRT

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98 Atul Chandra, no. 89.

99 "CATS", Hindustan Aeronautics Limited at https://hal-india.co.in/research-development-details/cats (Accessed on 17 September 2024)

100 Sameer Joshi, CEO, NSRT, during a discussion with the author in May 2024.

101 Yuvraj Tyagi, "India's HAPS prototype achieves landmark flight, paving the way for Stratospheric Operations", *Republic World*, 24 December 2023 at https://www.republicworld.com/defence/defence-technology/india-s-haps-prototype-achieves-landmark-flight-paving-the-way-for-stratospheric-operations (Accessed on 5 July 2024).

The HAPS programme was taken forward when NSRT was selected for the Indian Navy's Open Challenge-9 for the development of the operational HAPS platform in November 2023.[102] The Indian Navy had signed a deal with NSRT in March 2024 to develop a high-altitude pseudo-satellite for maritime surveillance under the iDEX initiative. The NSRT would develop a HAPS weighing up to 450 kg that would operate at an altitude of around 20 km, have 90 days endurance and carry a payload of 35 kg. The payloads could comprise Electro-Optic / Infra-Red (EO/IR) cameras, lightweight radars and other sensors.[103] In the meantime, NSRT HAPS set the national record of flying for 27 hours at an altitude of 26,000 feet as part of its envelop expansion in May 2024.[104]

The Council of Scientific and Industrial Research-National Aerospace Laboratory (CSIR-NAL) also developed a HAPS prototype. Its scale model with a wingspan of 11 metres and weight of 23 kg, flew for eight hours at an altitude of three kilometres in May 2024. The NAL's full-scale HAPS with a weight of 150 kg, a payload of 15 kg, a wingspan of 30 meters, an endurance of 90 days and an operating altitude of 17-20 km, is likely to be made operational by 2027.

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102 "Results for Indian Navy Open Challenge 9.0 (Batch 1)", IDEX, 13 November 2023 at https://idex.gov.in/sites/default/files/2024-03/Results%20for%20Indian%20Navy%20Open%20Challenge%209.0%28Batch%201%29_000%281%29%20%281%29%20%281%29%20%282%29.pdf (Accessed on 5 July 2024).

103 "Indian Navy signs deal with NewSpace Research & Technologies to develop high-altitude pseudo-satellite for maritime surveillance", Indiansentinesls.com, 14 March 2024 at https://www.indiasentinels.com/defence-industry/private/indian-navy-signs-deal-with-newspace-research-technologies-to-develop-high-altitude-pseudo-satellite-for-maritime-surveillance-6277 (Accessed on 5 July 2024).

104 Uttwal Shrotryia, "New Space High Altitude Pseudo-Satellite Completes Another Milestone - Flies for over 27 Hours at 26,000 feet", *Swarajya*, 16 May 2024 at https://swarajyamag.com/defence/newspaces-high-altitude-pseudo-satellite-completes-another-milestone-flies-for-over-27-hours-at-26000-feet (Accessed on 5 July 2024).

The NSRT HAPS is being developed for the defence forces while NAL is developing HAPS for non-military applications.[105] However, the development of HAPS by NSRT and NAL could involve duplication in R&D and sub-optimal utilisation of national resources. HAPS, being a niche programme, has several challenges, including the need for more capable solar cells and battery packs for day and night operation. In addition, HAPS with slow speed and low rate of climb, needs a suitable launch location and favourable weather for a long-duration climb to an altitude of 15-20 km that could take about 15-20 hours.[106]

Operationalisation and Induction Challenge

The biggest challenge of most of the indigenous defence UAV development programmes has been the uncertainty about their operationalisation and induction. It is important that the challenges of indigenous defence UAVs are identified and addressed. The induction of indigenously designed products needs to be prioritised to ensure that these technologies are preserved. The challenges of funding indigenous UAV development programmes or their non-induction, leads to discontinuation and disincentivisation of the development, refinement and upgrade of not only UAVs, but also critical subsystems, sensors, payloads, etc. that are crucial for *atmanirbharta* and establishing a foothold in global market.

Development of Indigenous Sub-Systems

During the development of *Tapas*, several indigenous technologies, sensors, payloads, software and components were developed by

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105 "High-Altitude Tech Race Heats Up: NAL and new space Vie for HAPS Supremacy", IDRW.org, 13 May 2024 at https://idrw.org/high-altitude-tech-race-heats-up-nal-and-newspace-vie-for-haps-supremacy/ (Accessed on 5 July 2024).

106 Kalyan Ray, "NAL successfully tests solar-powered 'pseudo satellite': UAV can float in air for days", *Deccan Herald*, 10 February 2024 at https://www.deccanherald.com/india/nal-successfully-tests-solar-powered-pseudo-satellite-uav-can-float-in-air-for-months-2889257 (Accessed on 5 July 2024).

various DRDO laboratories that include Flight Control Computer, Synthetic Aperture Radar (SAR), Data Link, Medium Range Electro Optic (MREO) system, Satellite Navigation System, Space- Based Augmentation System (SBAS), foldable landing gear, ATOL Ground Control System (GCS), Flight Simulator and other components. The ADE, the Defence Electronics Application Laboratory (DEAL)[107], the Vehicle Research and Development Establishment (VRDE), the Combat Vehicle Research and Development Establishment (CVRDE)[108], other laboratories of DRDO and private industry made significant contributions to not only the development of SRUAV and *Tapas* UAVs, but also several enabling technologies. Some of the indigenously developed technologies are discussed below.

Aero Engines

India currently imports almost all kinds of aero-engines except a few being used in missile programmes. The future trajectory of India's indigenous manned and unmanned aircraft development programmes hinges on aero engines. India's first indigenously designed fighter, *Hindustan Fighter-24* (*HF-24*) also known as the *Marut* fighter development programme of the 1950s and 1960s, suffered due to non-availability of aero-engines and lack of persistence in the engine upgrade programme. The Orpheus engine of the *HF-24* fell short of the thrust requirement. Indian engineers were pursuing an upgrade programme to increase the thrust of the Orpheus engine by design improvements as well as fitting the after burner. However, the engine upgrade programme was not pursued.

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[107] "Defence Electronics Application Laboratory", DRDO at https://www.drdo.gov.in/drdo/labs-and-establishments/defence-electronics-application-laboratory-deal (Accessed on 8 June 2024).

[108] "Retractable Landing Gear Systems for *Rustom-II* (*Tapas*) UAV", Defence Research and Development Organisation at https://www.drdo.gov.in/drdo/retractable-landing-gear-system-rustom-ii-tapas-uav (Accessed on 10 June 2024).

<u>Kaveri Jet Engine</u>–The *Kaveri* aero-engine is an opportunity for India to develop an indigenous propulsion system. The GE F-404-IN20 engine produces 85 kN thrust[109] while the indigenous *Kaveri,* designed for 80 kN[110] could achieve 73-75 kN. The DRDO is planning to integrate the current *Kaveri* engine on LCA Trainer aircraft. In addition, DRDO is planning to develop *Kaveri 2.0* with a thrust of 83-85 kN for LCA Mk-1A.

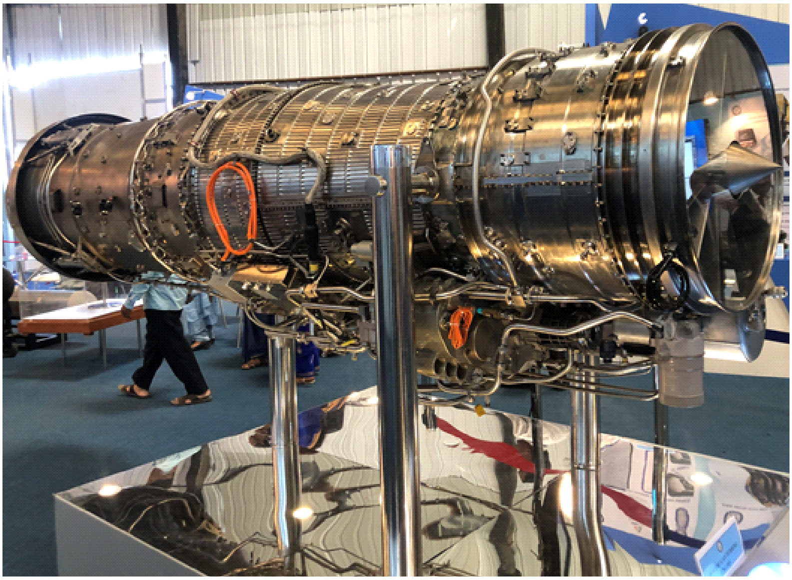

Fig 8. Kaveri Jet Engine, GTRE, courtesy author

The non-afterburner variant of the *Kaveri* engine with a thrust of about 48 kN is being developed for RPSA. It is scheduled to undergo high-altitude testing at a foreign test site in the second half of 2024. Kaveri

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109 "F-404 aero engine", GE Aerospace at https://www.geaerospace.com/sites/default/files/2022-01/F404%20Family%20Data%20Sheet_UPDATED.pdf (Accessed on 10 July 2024).

110 "*Kaveri*", DRDO at https://www.drdo.gov.in/drdo/kaveri (Accessed on 10 July 2024).

is likely to be certified in 2025-2026.[111] India can also develop the turbofan version of *Kaveri* for its HALE UAV.[112]

Kaveri is the most important aeroengine development programme for India's *atmanirbharta* in propulsion technology. The aeroengine is the pillar of any aviation manufacturing programme. *Kaveri* has made significant progress in the last few years despite falling short of the maximum thrust requirement of the LCA Mk-1A fighter aircraft. The GTRE has managed to develop 6-8 prototypes of the core *Kaveri* engine that reach a technology readiness level of about 70 kN against the requirement of 80 kN.

The aeroengine programme has moved at a slow pace and future development of the aeroengine would depend upon allocation of the funds that are awaited. It is estimated that about Rs 20-30,000 crores are required to build an indigenous engine. The allocation of these funds is essential to cross the most critical indigenous aeroengine barrier, which is essential for the growth of Indian aviation and UAV industry.[113] The success of *Kaveri* would give confidence about the ability of Indian industry to design, develop and manufacture aero-engines and reduce dependence on imports.[114]

Internal Combustion (IC) Engines–The Indian drone industry imports almost all the drone engines from 25 kg to *Tapas*-class MALE

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111 "India's *Kaveri* Engine Edges Closer to Take off from dry *Kaveri* to *Kaveri 2.0* for LCA Tejas Mk-1A Fleet", IDRW.org at https://idrw.org/indias-kaveri-engine-edges-closer-to-takeoff-from-dry-kaveri-to-kaveri-2-0-for-lca-tejas-mk1a-fleet/ (Accessed on 10 July 2024).

112 Raunak Kunde, "DRDO and GTRE to Integrate Dry *Kaveri* Engine Derivative into LCA-Tejas Trainer Aircraft", IDRW.org, 6 June 2024 at https://idrw.org/drdo-and-gtre-to-integrate-dry-kaveri-engine-derivative-into-lca-tejas-trainer-aircraft/#google_vignette (Accessed on 10 June 2024).

113 Nabanita R. Krishnan, former Director (ITM), DRDO, Roundtable on 'Atmanirbharta in UAS@2030' at MP-IDSA, 10 July 2024.

114 "Samvad, Exclusive Interview with Dr Samir V Kamath", Sansad TV, 4 June 2024 at https://www.youtube.com/watch?v=eoJv00pumT4 (Accessed on 8 June 2024).

UAVs. A rotary engine was developed for the *Nishant* and *Panchi* tactical UAVs. The *Rustom-1* (SRUAV) uses imported engine and *Tapas* is currently using the imported 168 HP Astro E4 Engine. The VRDE, a DRDO laboratory, has developed 180 HP Diesel engines and it is developing a 220 Horsepower diesel engine for future use[115]. Simultaneously, the VRDE is likely to pursue another programmme to indigenously develop 180 Horsepower IC engines with twin turbo-chargers. The development of 220Horsepower diesel engines for *Tapas* followed by the development of 180 Horsepower IC engine with twin turbo chargers indicates inconsistencies and lack of alignment with the user requirements. The two different types of engines for the same class of UAV indicates inconsistency in engine design and lack of coherence with UAV development programmes.

Turboprop Engine–India does not produce turboprop engines, and a turboprop engine of about 1200 Horsepower would be required for the MALE/ HALE class of UAVs. This engine can also be used as a propulsion system for indigenous manned transport aircraft, if India decides to develop its light-to-medium transport aircraft.

Light Weight Airframe

Tapas struggled to meet operational requirements due to its weight. The requirement of developing a lightweight airframe for UAVs has been a challenge for India. Carbon fibres of higher strength and modules (of the class of Toray T700 or better) are required for indigenous UAV and aviation development programmes.[116]

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115 Raunak Kunde, "*Tapas* Commences Taxi Trials with indigenous Engine", IDRW.org, 22 February 2023 at https://idrw.org/tapas-commences-taxi-trials-with-indigenous-engine/#google_vignette (Accessed on 10 June 2024).

116 Manneck E. Behramkamdin, Vice-President, Godrej Aerospace, Godrej & Boyce Mfg. Co. Ltd, Mumbai, Roundtable on 'Atmanirbharta in UAS@2030', MP-IDSA, 3 May 2024.

Avionics

Indian engineers, public and private entities have developed simplex, duplex and quadraplex avionics architectures, Synthetic Aperture Radar (SAR), MREO, etc. Indian companies have the capability to design and develop both hardware and software. Many Indian entities are developing avionics systems and they need development and procurement support to improve design, quality and scale-up manufacturing.

Landing Gear

The traditional hydraulic landing gears with electro-mechanical systems are heavy. They create weight management challenges for the modern UAVs and aircraft. There is a need to take a more proactive approach and develop of innovative, efficient and lightweight landing gears.

Command, Control and Communication Systems

Indian DRDO laboratories and DPSUs have gained significant experience in the development of Automatic Take-Off and Landing (ATOP) systems, waypoint navigation, UAV simulators, GCS software, advanced datalinks, satellite communications, etc. These technologies need to be transferred to private sector companies, MSMEs and start-ups, or efforts should be made to miniaturise and optimise them for use on smaller and lighter UAVs and aviation platforms.[117]

Military UTM and Enabling Technologies

Indian armed forces posess the *Searcher Mk-1*, *Searcher Mk-II*, *Heron, Harop,* small ISR and swarm UAS. In the next couple ofyears, Indian armed forces and the Central Armed Police Forces (CAPFs) are expected to procure about 3000 drones in the small to medium weight categories. These drones would be able to operate from low to high-altitude areas, which could create collision hazards between drones as well as between drones and manned aircraft. Therefore, there is a need

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[117] Ibid.

to develop military UTMs, which would have the following characteristics:

- The civil drone would primary depend on collaborative detection technologies. However, the military UTM would have the capability to detect small UAVs through collaborative and non-collaborative detection identification and tracking technologies.

- The military UTM would require both collaborative and non-collaborative detection technologies. The validation of collaborative detection is needed for real-time tracking of friendly drones while non-collaborative detection technologies like radars are needed to detect small and slow flying rogue drones.

- The military UTM of the Air Force would have a suitable network to provide interoperability with the Army, Navy, CAPFs, and civil UTMs.

- The feed from the civil UTM to the military UTM is essential while the vice-versa may not be desirable. The military UTM requires feed from the civil UTM to maintain separation as well as for detection and identification of rogue drones.

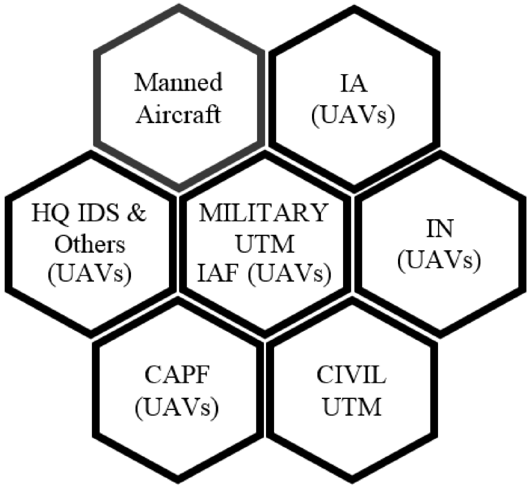

Fig.9. Sample Military UTM, courtesy author

Significance of Indigenous Technologies

The SRUAV and *Tapas* UAVs, components, sensors and payloads are critical technologies that take time to develop. Indian private sector companies also have the capability to develop many systems in India however, they require funding and testing support, and assurance of procurement of Minimum Order Quantity (MOQ), to survive.

In the large drone segment, the success of indigenously developed SRUAV, *Tapas*, RPSA, and *Archer-NG* UAVs by the ADE, CATS, HAL and HAPS by NAL and NSRT could take India towards the the of self-reliance. The common attribute of all these drones is that Intellectual Property Rights (IPRs) of all these drones would rest with Indian entities. As of now, the number of sub-systems, components, materials, sensors and payloads being developed by the ADE in collaboration with other DRDO laboratories and HAL, are more than those being developed by private industry.

The indigenous technologies are essential for self-reliance as they are either denied by exporting countries in a ToT arrangement, or are not considered commercially viable by the domestic industry. The import of technologies brings in strategic dependence on foreign Original Equipment Manufacturers (OEMs) and thus there is a need to preserve and utilise these technologies for being self-sufficient. The indigenous technologies, systems, sensors and payloads provide flexibility in indigenous development programmes, as they can be used for multiple UAV development programmes.

Defence UAV Development by Private Sector and Challenges

Indian private sector companies led by start-ups and MSMEs have demonstrated their capability to develop a wide variety of small drones less than 500 kg for civil-military applications. Some examples of drones that were inducted or are in the process of being developed or inducted by the armed forces, are given in Appendix "B".

The Mehar Baba Competition of the IAF [118]and iDEX[119] have made significant contribution to the development of swarm UAVs, logistics supply, tethering UAVs, ISR and other UAVs being developed by the private industry. However, most of these UAVs fall in the small UAV category. A few private companies have the capability to undertake indigenous development of bigger and higher-performance UAVs. Some of the challenges faced by the Indian private sector companies developing large UAVs are as follows:

(a) The private sector companies remain dependent on import of critical components. There is little effort to close gaps in critical technologies.

(b) A few Indian companies that are developing core technologies, components, subsystems, sensors and payloads face challenges in procurement of their products. The QRs for procurement of UAVs, normally do not seek indigenous critical components, materials, software, sensors, payloads, etc. and many Indian UAV manufacturers find it easier to import such components.

(c) The investment by private sector companies except for start-ups and MSMEs on R&D is much lower than global leaders.

(d) The start-ups and MSMEs are vulnerable to acquisition by foreign entities.

Defence UAV Vulnerabilities

In the small defence UAV segment, innovative drones like swarm, logistics, ISR, loitering and tethered drones are being developed by private companies. The details of some of the drones developed and supplied by the Indian companies are placed at Appendix 'A'.

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118 "Mehar Baba Competition-II", Indianairforce.nic.in at https://indianairforce.nic.in/mehar-baba/ (Accessed on 6 July 2024).

119 "Multi-Utility Long Endurance Drone (NSUAS-Class) for use in Maritime Domain for C4ISR Duties", Innovation for Defence Excellence (iDEX) at https://idex.gov.in/challenges-cpt/1065 (Accessed on 6 July 2024).

Some of the UAVs being procured by defence forces have inherent vulnerabilities as these UAVs are assembled mostly from imported critical components. This aspect came to limelight when the contract for 200 medium-altitude logistic drones was cancelled by the Indian Army in August 2024 due to vulnerabilities from imported components. Three companies were identified as defaulters.[120] The following needs to be examined:

(a) The companies that were to supply UAVs to Indian Army were certified by the DGCA. The DGCA certifies UAVs for airworthiness and not for security. The cancellation of the above contract raises concerns about security and inherent vulnerabilities of the DGCA-certified UAVs. This could compromise operations by the Indian defence forces.

(b) The vulnerabilities originate from critical components. It would be prudent to examine whether indigenous components were sought in the UAVs in the Request for Proposal (RFP) to reduce vulnerabilities.

The trajectory and indigenous content of the UAVs developed by both public and private sector companies needs to be scientifically assessed to reduce vulnerabilities and if required propose course corrections.

Assembly/Integration of Defence UAVs in India

The effort of global OEMs has been to assemble their products in India with manufacturing of non-critical systems by their Indian partners in India. In these programmes, the license of critical systems would rest with foreign OEMs and Indian companies would not be able to upgrade or develop future variants of such UAVs.

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[120] "Army puts on hold acquisition of 200 drones from Daksha Unmanned Systems", *The Hindu Business Line*, 28 August 2024 at https://www.thehindubusinessline.com/news/national/defence-ministry-cautions-firms-using-chinese-parts-for-drones/article68573070.ece (Accessed on 1 September 2024).

The Army and the Navy acquired two Hermes-900 (renamed as *Drishti-10*) surveillance UAVs each from Adani Defence Systems under the emergency powers. It was claimed that *Drishti-10* UAVs had achieved 70 per cent indigenous content; however, the following questions need to examined:

(a) Would Indian company have control of IP?

(b) Would it be able to modify and upgrade these UAVs on its own?

(c) Is it planning for co-development of UAVs with joint IP?

(d) How do we assess and validate the IC claimed by the Indian company?

The trajectory and roadmap for indigenous development by the Indian public and private sector companies involved in collaborations with foreign OEMs needs to be scientifically examined to understand its contribution to IP creation and indigenous development.[121]

Co-Development and Co-Production of Defence UAVs

India is encouraging Indian companies and global OEMs to undertake co-development and co-production of defence technologies including UAVs. The endeavour is to encourage joint development of niche, innovative and emerging technologies that meet the requirements of Indian, partner country and global markets. This is a win-win arrangement for both partners. This approach is apparent in the India-US Defence Technology Trade Initiative (DTTI). Some global players have shown interest in manufacturing UAVs in India; however, they have been cautious in co-development and co-production. There is little progress in co-development / co-creation with joint IPRs or shared IPRs. This needs to change.

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[121] "Army to Get *Drishti-10* Drones to Boost Surveillance ON Pak Border: Report", NDTV, 10 May 2024 athttps://www.ndtv.com/india-news/army-to-get-drishti-10-drones-to-boost-surveillance-on-pakistan-border-report-5634965 (Accessed on 11 July 2024).

Technology Collaborations with Global Partners

India and the USlaunched the Indo-US Initiative on Critical and Emerging Technologies (ICET)[122] and the Indo-US Defence Acceleration Ecosystem (INDUS-X)[123] in January 2023 and June 2023 respectively. Indian companies are establishing similar technology collaborations with other countries. However, these collaborations have the following limitations:

(a) There are collaborations between Indian defence companies and defence forces of foreign collaboration partners while there are no technology collaborations between Indian defence forces and the global partner companies.

(b) Indian companies collaborating with global partners and OEMs predominantly focus on assembling and low-value manufacturing in India. There are very few joint development projects between Indian entities and global partners and OEMs aimed at joint IP creation.

The lack of collaboration between Indian defence forces and innovators from other countries is also due to lack of R&D structures in the Indian defence forces.

Creating Globally Competitive UAV Companies in India

The creation of Indian UAV manufacturing giants with global reach like Lockheed Martin, Sukhoi, Boeing, etc. would require transformation

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122 "Roadmap for US-India Defence industrial Cooperation", US Department of Defense, 5 June 2023 at https://media.defense.gov/2023/Jun/21/2003244834/-1/-1/0/ROADMAP-FOR-US-INDIA-DEFENSE-INDUSTRIAL-COOPERATION-FINAL.PDF (Accessed on 25 August 2024).

123 "Factsheet: India-US Defence Acceleration Ecosystem (INDUS-X)", 21 February 2024 at https://www.defense.gov/News/Releases/Release/Article/3682879/fact-sheet-india-us-defense-acceleration-ecosystem-indus-x/ (Accessed on 25 August 2024).

of India's technology development trajectory. India would have to follow a different trajectory from the one being followed in its two leading industries, i.e., Automobiles and Information Technology (IT). The Indian automobile industry is yet to build futuristic automobiles that compete at the global level and establish their distribution base within the leading global automobile manufacturing countries. In addition, a few global OEMs manufacturing cars in India have created an adverse trade balance for India.[124] In the IT sector, India has been a feeder to global IT leaders and it is yet to create products that have a global presence.

India has been pursuing both indigenous development as well as technology collaborations with global OEMs in the defence and industrial sectors since independence. However, India's dependence on import of defence equipment has remained high and its trajectory towards *atmanirbharta* has been slow. The Indian UAV industry led by start-ups and MSMEs has the potential to change this trajectory and become an innovation and IP-led globally competitive industry. The transformation of Indian industry from license manufacturing to an IP-led industry would require creation of mechanisms to validate claims of indigenous development and IP creation. The Indian companies followed the following approaches:

(a) Indian companies indigenously developing drones and sub-systems.

(b) Indian entities – both public and private – obtaining ToT from global OEMs and claiming high IC under 'Make in India'.

(c) A few Indian public and private sector companies pursuing Joint development with global OEMs.

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124 "Korean auto giants Hyundai, Kia, have cost India billions of dollars in trade deficit, says Piyush Goyal", *The Economic Times*, 26 February 2023 at https://economictimes.indiatimes.com/news/economy/foreign-trade/korean-auto-giants-hyundai-kia-have-cost-india-billions-of-dollars-in-trade-deficit-says-piyush-goyal/articleshow/98248411.cms?from=mdr (Accessed on 11 July 2024).

Many companies manufacturing UAV, sensors, components, software and payloads claim high IC, which is becoming difficult to validate. Therefore, a policy and mechanism is needed to ascertain indigenous design, development, manufacturing and IP creation to ascertain their contribution to IP generation and *atmanirbharta.* The companies making a genuine contribution to *atmanirbharta* in UAV and other technologies need to be identified and nurtured. The following isrecommended:

(a) Formulate a mechanism to scientifically ascertain the extent and trajectory of IC in IDDM projects.

(b) Create a mechanism to ascertain IC content in ToTs. Monitor indigenisation trajectory of Indian partners in terms of types of critical systems, components, software, materials, sensors, payloads, etc. In addition, the ability to modify, upgrade and develop future variants individually by the Indian entity or through joint development would indicate strength of such collaborations.

(c) Ascertain extent of workshare in technology development and IP creation by the Indian entity. Also, the ability, control and plan of the Indian entity in developing critical and vulnerable components, systems and undertaking upgradation and develop future variants.

The certification and validation mechanism to ascertain, validate and certify IC based on materials, software and components would bring transparency and prevent misuse of IDDM acquisition procedures. This will encourage Indian public and private sector companies collaborating with global OEMs to focus on technology, innovation, *atmanirbharta* and global presence. This will enhance acceptability of Indian drones in the global markets and prevent assemblers from wrongly claiming high IC. Creating globally competitive Indian UAV companies would require enhancing indigenisation, improving quality, pursuing design improvements, building cost competitiveness, creating an edge, and developing advanced and future variants.

Academia in Defence UAV Development

Academia and its start-ups are not being optimally leveraged to develop critical technologies and fill technology gaps. Academia has several well-qualified globally renowned academicians with experience of working in global academic institutions and industry. Some of them have the experience to leverage their academic knowledge and practical experience of technology development with industry to develop operational and commercially viable UAVs, sensors and payloads in India. Indian academia is also increasingly incubating start-ups. The participation of academia-incubated starts-ups in iDEX and other innovation competitions has been beneficial. However, most of the technologies developed through these competitions are low-cost technologies.

Indian defence forces and DPSUs have signed MoUs with the DRDO for studies and technology development with academic institutions. However, the scope of such collaborations has been limited to studies and facilitating demonstrations of low-cost technology prototypes developed by start-ups.

Academia has inducted many professional experts from the defence forces, government institutions and industry, as professors of practice to address the gaps between theory, prototypes and operational / commercially viable products. The efforts of some professors of practice to collaborate with defence forces and seek funding to jointly develop high-technology high-value UAVs, engines, avionics, payloads etc. has not achieved the desired degree of success. This seems to be due to the reluctance of academia, incubation centres and other stakeholders to make large investments in technologies where there are uncertainties about the outcome.

The joint development of UAVs and other technologies can contribute in filling the technology gaps; however, we should be prepared for failure.[125] Indian private industry is focused on multi-copters and more effort is needed to develop fixed-wing UAVs of different sizes and capabilities. The Indian drone industry remains dependent on aero engines, light-weight radars, sensors, payloads, avionics, communication

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125 Lt Gen P.R. Shankar in his address at the Roundtable on 'Atmanirbharta in UAVs@2030' at the Manohar Parrikar Institute for Defence Studies and Analysis (MP-IDSA), 3 May 2024.

systems, INS(full form), multi-spectral payloads, etc. Lt Gen Shankar (Retd), Professor of Practice with IIT Madras, recommended a three-pronged spiral development approach for indigenous development of UAVs, sensors and payloads in collaboration with defence forces and academia, which is as follows:

(a) In the first category, launch indigenous development of 25 Kg All up Weight (AUW) fixed-wing UAV powered by IC engine with 100 km range, 4 Km altitude and 6 to 8 hours of endurance. Its development could take up to two to three years.

(b) In the second category, launch development of IC engine-powered 150 kg AUW UAV with 5 km maximum altitude, its development will take between four to five years.

(c) In the third category, develop IC engine-powered 650 kg AUW fixed- wing UAV with a range of 500 Km, a maximum altitude of 5 Km and an endurance of 12 hours. Its development could take between six to eight years.

It may be necessary to initially use a few of the Commercially Off-the-Shelf (COTS) systems. However, efforts need to be made for systematically but progressively achieving maximum indigenous content in a time bound manner. In addition to UAVs, a programme for the indigenous development of critical sub-systems is also needed. The following approach is recommended for the indigenous development of materials, navigation systems, ground control systems (GCS), sensors, payloads, etc:

(a) Develop indigenous avionics, communication systems, GCS, etc;

(b) Develop vision-based navigation systems to bring down the cost;

(c) Develop and miniaturise advanced payloads such as multi-spectral payload, SAR, etc. and write robust algorithms for interpretation of SAR data;

(d) Develop and adopt advanced materials, manufacturing methods and structural designs.

The collaboration between academia, defence forces, DRDO, ISRO and industry by leveraging strengths of each partner, is essential to develop robust and advance indigenous UAVs and systems.

Indian private sector companies and innovators also face challenges due to inadequacy of an enabling UAV development ecosystem, availability, cost, locations and other challenges.

DEFENCE UAV DEVELOPMENT ECOSYSTEM CHALLENGES

The design, development and manufacturing of defence equipment in the past was led by the DRDO and DPSUs. The Indian government has made special efforts to enhance participation of the private sector in the development of niche UAVs and other defence technologies. The development of defence equipment requires creation of an ecosystem comprising testing facilities, formulation of standards, standardisation in manufacturing, certification and investment in R&D. The defence ecosystem comprising testing and certification was created for DRDO and DPSUs. DRDO and DPSUs used global standards for developing their products and there were no testing and trial-based Indian standards, as they were not developing niche and innovative defence products. However, development of niche UAVs by Indian entities has necessitated a change in this trend. Therefore, India needs to take the lead in the formation of trial-based standards for UAVs and other emerging technologies.

Defence UAV Testing Infrastructure

The existing defence testing facilities have been opened up for the private sector. However, the number of defence testing facilities and their availability is limited due to DRDO's and DPSUs' requirements. In order to overcome these limitations, the Defence Testing Infrastructure Scheme (DTIS)[126] was launched to build state-of-the-art

[126] "Defence Testing Infrastructure Scheme (DTIS)", Director General of Civil Aviation (DGCA) at https://dgqadefence.gov.in/dtis (Accessed on 6 July 2024).

testing infrastructure in collaboration with Centre/ state governments and industry with an outlay of Rs 400 crores in May 2020.

Seven testing sites comprising four in Tamil Nadu and three in Uttar Pradesh were approved. The Memorandum of Understanding (MoU) for the three testing sites was signed between the MoD and Tamil Nadu Industrial Development Corporation Limited (TIDCO) on 2 July 2024. The DTIS provides 75 per cent funding while the remaining 25% is provided by the Special Purpose Vehicle (SPV) comprising a consortium of Indian private entities and the state/ central government. Out of these seven test facilities, only one is being built for testing UAVs. Keltron, an undertaking of the Government of Kerala, leads the UAV testing facility SPV, where private sector companies are consortium members.[127] This facility with a limited ground operations surface and airspace is capable of testing predominantly rotary UAVs. It does not have a runway and adequate airspace to test fixed-wing long-range UAVs.

Engine Testing Facilities

Kaveri engines are undergoing high-altitude testing at foreign testing facility due to the absence of high-altitude wind tunnel and test aircraft in India.[128] India aims to develop jet engines that are more powerful, for *Tejas Mk-2* and Advanced Medium Combat Aircraft (AMCA). India would need high-strength test rigs to test aero engines for 110-130 kN power, high-altitude wind tunnels and test aircraft to facilitate expeditious testing and certification of aero engines in India. The indigenous engine testing facilities would result in reduction in development timelines and cost of testing of aero engines. This would

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[127] "MoD inks MoU to set up testing facilities in Unmanned Aerial System, Electronic Warfare & Electro Optics domains in Tamil Nadu Defence Industrial Corridor", Ministry of Defence, PIB, 2 July 2024 at https://pib.gov.in/PressReleseDetail.aspx?PRID=2030282 (Accessed on 6 July 2024).

[128] "*Kaveri* Derivative Engine to be prepped for Upcoming Trials in Russia", 9 September 2023 at https://idrw.org/kaveri-derivative-engine-to-be-prepped-for-upcoming-trials-in-russia/ (Accessed on 26 June 2024).

enable developing one of the most critical technologies that is essential for *atmanirbharta* in aeronautics and UAVs. DRDO realising limitations and challenges of aero-engines testing, had proposed funding for high altitude test facilities in August 2024.[129]

Accreditation and Availability of Laboratories The accreditation of NABL and other laboratories of DRDO, DPSUs, Defence Forces and other entities is needed to support indigenous development by public and private sector entities developing defence UAVs. Similarly, availability of these laboratories 24 hours a day, 7 days a week and 365 days a year at a reasonable cost, would be a powerful enabler.

Defence UAV Standards

The defence UAVs are required to operate in special operational conditions and thus need greater security and ruggedness as well as defence specific standards compared to the civil UAVs. Indian defence forces are acquiring UAVs from various private sector entities. These UAVs have indigenous as well as imported critical components, which could create safety, security and interoperability challenges. The drones acquired by various formations within the Indian Army, Navy, Air Force and CAPF with components from different manufacturers, would need to be integrated with their air traffic and air defence systems. In addition, they need to be interoperable with drones acquired by various entities within the organisation as well as with other organisations. Therefore, there is a need to formulate standards for defence UAVs and components developed by Indian companies, to bring up the quality, facilitate interoperability and enhance security.

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[129] Raunak Kunde, DRDO Seeks Funds for Critical high Altitude Test Facility for Jet Engines, 27 August 2024, at https://idrw.org/drdo-seeks-funds-for-critical-high-altitude-test-facility-for-jet-engines/ (Accessed on 17 September 2024).

Chapter 4

Mlitary-Civil Fusion and Whole of Government Approach

The US uses the term 'Civil-Military Integration' (CMI) for the integration of military and civil technology and industrial bases. The US CMI has seen several vicissitudes since the Second World War in which civil and military industries have gone through three stages, comprising pre-Cold War, Cold War and post-Cold War periods. In these three stages, US civil and military industries were coupled, decoupled and coupled again, to form CMI in 1994. Chinese examined the CMI and articulated their Military-Civil Fusion (MCF) strategy to harness capabilities of both, civil and military technologies to enhance the scale of production and economic viability. The Academy of Ocean of China has examined these developments in detail in an article in 2018.[130]

US CMI for National Industrial Base

The CMI in the US was first achieved when the Defence Technology and Industrial Base (DTIB) was integrated with Commercial Technology and Industrial Base (CTIB) during the Second World War to leverage strengths of both for technology development. The DTIB focuses on developing and manufacturing defence equipment like aircraft, tanks, ships, etc. while CTIB is focused on developing and manufacturing commercial machines, equipment such as cars, trucks, commercial ships, civil aircraft, other machines and equipment.

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130 "The development of civil-military Integration in the US has gone through three stages", at https://aoc.ouc.edu.cn/2018/0722/c9824a207242/pagem.psp (Accessed on 15 June 2024).

After the end of the Second World War, the defence and commercial technology and industrial bases segregated. As a result, DTIB was largely isolated from the commercial base and thus lost some of the benefits of larger number of buyers. This isolation raised the cost of defence goods and services and reduced the defence industry's access to fast-moving commercial technologies. It also denied commercial firms the chance to exploit the results of large national-level defence science and technology investments.

In September 1994, the US Congress', Office of Technology Assessment, published a study titled *Assessing the Potential for Civil-Military Integration: Technologies, Processes and Practices* that aimed at bridging the critical gaps between the two industries. According to this study, civil-military integration is defined as the process of merging the DTIB and the larger CTIB into a National Technology and Industrial Base (NTIB). The NTIB includes non-commercial elements such as public utilities and other non-Department of Defense (DoD) government procurements.[131] The NTIB optimised the use of DTIB and CTIB by both civil and military users, which helped in increasing the scale of manufacturing and cost competitiveness of their products.

The NTIB is also part of the Global Technology and Industrial Base. The US has R&D and technology development initiatives around the world and it leverages its global technology initiatives as well as global talent for developing niche technologies. The CMI involves an integrated base, common technologies, processes, labour, equipment, materials, and / or facilities to meet obit defence and commercial needs. The decisions to use integrated resources are based on the same technical, legal and economic reasoning that commercial firms use when servicing global markets. The CMI brought cost savings and increased technology transfer between the civil and military industries, though greater benefits are realised in the longer time frame. The most significant aspect of

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[131] "Assessing the Potential for Civil-Military Integration: Technologies, Processes and Practices", US Congress, Office of Technology Assessment, September 1994 at https://digital.library.unt.edu/ark:/67531/metadc39728/m1/52/ (Accessed on 14 June 2024).

CMI is that it increases the viability of defence and civil industrial capability under economic constraints.[132]

China's MCF

China's MCF development strategy blurs the differences between civilian and military applications of dual-purpose technologies such as robotics, AI, aerospace, aero-engines, nuclear, semi-conductors, cyber, etc. The MCF is especially significant in aeronautics, space and drone technologies. The current MCF policy came into existence in 2012 and aimed at making China a technological and scientific power by 2050. The 27-member Chinese MCF Development Committee was established in 2017. The structure of MCF Committee is similar to India's Space or Atomic Energy Commission, with four functionaries in the Secretariat and twenty-three members.[133]

The MCF Development Committee is headed by President Xi Jinping with the Premier as the deputy head, the Executive Secretary and Executive Vice-Premier as the other members comprising Secretaries, Politburo members, members from the Chinese Military Commission (CMC) Departments, researchers and technology experts, ministers from various ministries and other relevant senior functionaries.[134] The MCF has been part of every strategic initiative taken by China ever since Xi Jinping became President in 2012, that include initiatives such as 'Made in China 2025' and the 'Next Generation Artificial Intelligence Plan'.[135] The MCF has led to parallel growth of government-led civil, military and private sectors.

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132 Ibid.

133 Cheng Li, "China's Military-Civil Fusion; Objectives, and Operations", *China-US Focus*, 30 August 2022 at https://www.chinausfocus.com/2022-CPC-congress/chinas-military-civil-fusion-objectives-and-operations (Accessed on 15 June 2024).

134 Ibid.

135 "Civil-Military Fusion: The Missing Link Between China's Technological and Military Rise", Council on Foreign Relations, 29 January 2018 at https://www.cfr.org/blog/civil-military-fusion-missing-link-between-chinas-technological-and-military-rise (Accessed on 15 June 2024).

In addition to the MCF Development Committee, the Chinese Military Commission (CMC) has the Science and Technology (S&T) and the Equipment Development Departments (EDD) that promote R&D, innovation and indigenous development. The S&T Department promotes strategic management of national defence science and technology and innovation, pushing for integrated development of military and civilian science and technology. The EDD is responsible for R&D, testing, authentication and information construction.[136]

Need for National MCTF in India

India does not have a national MCF or CMI policy, strategy and plan for any sector. This lack of integration between civil and military sectors leads to incoherence in technology development, sub-optimal utilisation of technology development resources and ecosystem. This affects the scale of manufacturing and cost competitiveness, especially at the global level. There is a need to formulate a National Military-Civil Technology Fusion (MCTF) policy, as there are multiple sectors that would benefit from such fusion. The name MCTF is proposed instead of MCF to emphasise the pre-eminence of technology collaboration.

Need for MCTF for Indian Aeronautics and Drone Sectors

The development of drone and aeronautics technology is led by the Ministry of Defence in India. The corresponding civil drone and aeronautics technology development is non-existent. In addition, the lack of a Military-Civil Technology Fusion (MCTF) policy, technology development structures and ecosystem, becomes a hinderance in the growth of domestic civil aeronautics and drone technologies.*Absence of Civil Aviation/Drone Atmanirbharta Policy*

The MoD under its defence *atmanirbharta* policy, regularly undertakes indigenous design and development projects. The MoCA on the other

136 "CMC", Ministry of Defence at http://eng.mod.gov.cn/xb/CMCDEPARTMENTS/index.html (Accessed on 26 June 2024).

hand, does not have a civil aviation / drone *atmanirbharta* policy. The *atmanirbharta* in aviation / drones was not included in the National Civil Aviation Policy-2016,[137] which is a limitation in achieving MCTF.

In the defence aeronautics sector, India has made significant progress in the last decade with the development of *ALH Mk-I, II*, *III* & *IV*; Light Combat Aircraft (LCA, Mk 1/ 1A & II), Hindustan Turbo Trainer-40 (HTT-40), *Saras* (Mk-1 &2), Dornier-228 and many more defence aircraft are being developed by Indian industry. India leveraged procurement of 56 C-295 aircraft to establish a manufacturing facility in India, though details of which critical systems of C-295 would be manufactured by Indian entities, remain unclear. On the other hand, Indian airline operators placed an order for 1100 aircraft worth $110 billion in 2023 with no local manufacturing or ToT. The corresponding impetus to develop and manufacture commercial and civil aircraft in India is absent due to lack of self-sufficiency in civil aviation and MCTF policies.

Lack of MCTF in Counter Drone Technologies

In the counter-drone technologies segment, India developed indigenous counter- drone solutions for the defence forces though the iDEX challenges. The counter-drone solutions for civil aviation and protecting the critical industries requires tweaking of counter-drone technologies to prevent collateral damage. However, there are no corresponding civil counter-drone technology development challenges due to absence of MCTF.

Lack of MCTF in Drone Technologies

In the defence drone sector, the Mehar Baba Swarm Drone Competition played an important role in evolution of drone swarm in India.[138] In addition, few defence drone-related problem statements

137 "National Civil Aviation Policy-2016" at https://www.aai.aero/sites/default/files/basic_page_files/Final_NCAP_2016_15-06-2016-3%20%281%29.pdf, (Accessed on 8 June 2024).

138 "Mehar Baba Competition-II", Indian Air Force at https://indianairforce.nic.in/mehar-baba/ (Accessed on 16 June 2024).

were included in the iDEX competitions.[139] However, no such competition has been launched in civil drone technology development to fill critical gaps in India's civil drone industry. The reliance on imports for civil drone critical systems and subsystems remains a major vulnerability and impediment in scaling-up manufacturing. The lack of MCTF is becoming a limitation in achieving the goal of India being a global drone hub by 2030.

The civil drones are being used in the agriculture sector with the launch of the Kisan Drone and Kisan Didi scheme. The drones are also being used for the Survey of Villages Abadi and Mapping with Improvised Technology in Village Areas (SVAMITVA) scheme. The Ministry of Agriculture, Ministry of Panchayati Raj and other Ministries also lack policies on *atmanirbharta*, procurement of indigenously designed drones and use of indigenously designed drones for commercial services.[140]

Lack of MCTF in Satellite Navigation

The future and outcomes of the Navigation with Indian Constellation (NAVIC) challenge launched by the MeitY on 15 August 2022 to build a indigenous satellite-based navigation system, remains uncertain. It has been a challenge for standalone civil navigation technology development with the potential to provide indigenous satellite navigation solutions.[141] The development of a suitable NAVIC receiver has been a slow process without user involvement. The lack of user involvement and assured procurements has been a major limitation in the development of indigenous technologies.

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[139] "Miniaturisation for Implementation of Mini and Micro Drone and DroneSwarms", iDEX, DISC 5 Challenges at https://idex.gov.in/challenges-cpt/506 (Accessed on 16 June 2024).

[140] Ministry of Panchayati Raj at https://svamitva.nic.in/svamitva_hindi/#:~:text=SVAMITVA%2C%20a%20Central%20Sector%20Scheme,%2D2021)%20in%209%20states(Accessed on 6 June 2024).

[141] "NAVIC Grand Challenge", Startup India, Department of Promotion of Industry and Internal Trade (DPIIT) at https://www.startupindia.gov.in/content/sih/en/ams-application/challenge.html?applicationId=62566a33e4b00f07df34a25e (Accessed on 15 August 2022).

This indicates a lack of synergy among the civil-military stakeholders. The MoD, MoCA and the Indian auto-industry – three potential users of NAVIC competition – could have joined it as partners. They could have been involved in the formulation of the problem statement, vetting of participants, development, trials and validation of NAVIC systems developed by the participants and could have provided assured orders. The MCTF could have resulted in rich dividends and a boost to *atmanirbharta* in satellite navigation.

Atmanirbharta in India is focused on defence aviation and defence UAV sectors. However, similar initiatives are needed in the civil aviation and drone sectors as well, to complement defence *atmanirbharta* initiatives and achieve MCTF.

Chapter 5

The Way Forward

The way forward proposes measures that would address policy, technology development and ecosystem challenges for civil and military drone manufacturing industries in India. The articulation of Military Civil Technology Fusion (MCTF) policies and other measures have been examined to bring synergy between the civil and military drone industries. The proposed measures are aimed at making the Indian drone industry a self-sufficient, globally competitive, innovation-led drone industry, and India a global drone hub by 2030. The way forward aims to transform India from a technology follower to a technology leader in the drone sector. The way forward has been divided into following categories:

(a) MCTF in UAVs

(b) Reforms in the civil drone sector

(c) Course Corrections in the defence UAV sector

The way forward in MCTF aims to bring synergy among central ministries, state governments, departments and other governments supported entities in the country. The course corrections in the civil and military drone sectors, have detailed recommendations related to policies, technology development and technology development ecosystem.

Military Civil Technology Fusion (MCTF)

This section proposes measures that would bring MCTF. These may require whole of the government approach? The whole government approach emphasizes that action is required by all ministries of the central government, state governments and all entities within the country. The recommendations for achieving MCTF in UAVs follow.

1. **National MCTF Policy:** There is a need to formulate a National MCTF policy that could apply to military-industry fusion in general.

2. **MCTF Policy for Drones**: Within the ambit of the National MCTF policy, articulation of the MCTF policy is necessary for indigenous development of drone technologies that complements R&D efforts, optimises utilisation of facilities/ resources, creates enabling provisions for the procurement of indigenously developed UAVs by all ministries, enables scaling-up of production, enhances quality in manufacturing, and makes export competitive.

3. **MCTF Commission / Committee**: The establishing of MCTF Commission or an empowered Committee on MCF headed by the Prime Minister isrecommended to address inter-ministerial coherence in developing multiple technologies including UAVs. The MCTF is essential for making India a developed nation by 2047 (also known as the Viksit Bharat@2047 mission).

The advances in civil drone technology would be leveraged to develop military UAVs and vice-versa. Joint and complementary civil and military technology development initiatives could also be launched to address common problems such as detect-and-avoid, UTM, etc. while preventing duplication., Enabling procedures also need to be developed to procure indigenously developed products.

Reforms in Indian Civil Drone Sector

The Indian civil drone sector needs major reforms to become an *anusandhan* se *atmanirbhar* sector, integrate drones in the Indian airspace and become globally competitive. Some of the key civil drone policy, technology development and ecosystem reforms and course corrections are deliberated below.

1. **Civil UAV Policy Reforms for Atmanirbharta**. The polices and schemes needed to support *atmanirbharta* in UAVs, critical components, assemblies, sub-assemblies, sub-systems, sensors, payloads, software, etc. are as follows:

    - **Formulate Policy on *Atmanirbharta* in Civil UAVs.** The MoCA or nodal ministry may formulate a policy on *Atmanirbharta* in Civil UAVs.

    - **Formulate Civil UAV Indigenously Designed and Developed Certification Policy.** Introduce Civil Drone

Indigenously Designed and Developed Certification (IDDC) policy to certify indigenously designed and developed UAV, components, software, sensors and payloads. The IDDC should be accorded to an entity having the IPR of design and the mandate to undertake design improvements, modifications and upgrades, In addition, the design or its designated Indian entity? should have the development and manufacturing capabilities in India.

- The DGCA or a designated nodal agency could be entrusted with responsibilities of evaluating and providing IDDC to civil drones. The DGCA or designated agency could build this capability by employing retired employees of defence certification and testing entities like CEMILAC and Aircraft Systems and Testing Establishment (ASTE).

- They may train, skill and upskill their technical personnel as required to undertake this task. This policy can be made applicable for aeronautics, defence and industrial sectors to recognise as well as incentivise indigenous design and IP creation.

- **Design Organisation Approval Policy for Start Ups**. DPIIT may Introduce Design Organisation Approval for startups that are involved in the design and development of aircraft, UAVs, airborne systems, airborne stores, components, sensors, payload, software, etc. through innovation initiatives.

- **Introduce DLI Scheme for Drones/ UAVs**. Review PLI Scheme for drones and drone components to formulate the DLI Scheme or "Abhikalpa-Abhinav Protsaahan Yojna"[142] to encourage indigenous design and innovations and reduce dependence on import for critical components. The scheme could have higher incentives for IDDM products to encourage

142 The term "Abhikalpa-Abhinav" is articulated by Wg. Cdr. B.S. Nijjar, Ex-Research Fellow, Centre for Air Power Studies (CAPS), New Delhi.

indigenous design and IP creation in UAV, components and sub-systems.

- **Trials-Based Policy Formulation by DGCA and AAI**. The drone and engineering directorates of the DGCA and AAI should review their respective approaches and take the lead in launching trial and validation initiatives to ascertain technology developments and introduce proactive polices on the lines of the US FAA and EASA of Europe.

2. **Structural Reforms.** The measures proposed to development indigenous drone technology through R&D and technology development are as follows:

   - **Designate Nodal Ministry for UAV Technologies**. The MoCA or a designated ministry could be made the nodal ministry to spearhead the development of UAV technologies in India and take ownership of the India as a Global Drone Hub@2030 mission.

   - **Launch National UAV Technology Mission**. Launch National UAV Technology Mission under the Principal Scientific Advisor's Office to overcome inter-ministerial and inter-departmental incoherence in developing critical, niche and enabling UAV technologies. It would work in collaboration with the nodal ministry and maintain supervision on development of civil-military UAV technologies. It would take measures to develop technologies that are needed to establish India as an self-sufficient and global leader in drone technologies.

   - **Create Civil UAV R&D Structures**. The MoCA and DGCA should create an R&D ecosystem on the lines of the Federal Aviation Administration (FAA) of the United States or the European Union Aviation Safety Agency (EASA). This would involve the creation of R&D structures, launching R&D initiatives and allocating budget for R&D in civil UAV technologies. The MoCA/ nodal ministry should take the lead and steer drone technology development initiatives. These initiatives should focus on development, validation and adoption of enabling technologies to integrate drones into

Indian airspace as well as develop niche and innovative UAV technologies.

3. **Civil UAV R&D and Technology Development Reforms**. R&D and technology development reforms and course corrections needed to develop UAV technologies, fill technology gaps in UAVs, critical components, sensors, payloads, materials, software, etc. and establish lead in some of niche technologies are enumerated below.

    - **National UAV Technology Fund**. A dedicated National UAV Technology Fund within the National Programme for funding of R&D should be earmarked for developing niche drone and airspace integration technologies, that are focused on filling specific technology gaps. In addition, the fund would be leveraged for developing propulsion systems, sensors, payloads, software, remote tracking, detect-and-avoid systems, UTM systems, etc. The Fund would also be leveraged for establishing national civil drone testing sites and undertaking validation trials of technologies.
    - **Launch Civil Drone/Aeronautics Technology Development Initiatives**. The MoCA or the designated nodal ministry should launch Civil drone technology development initiatives to develop niche and emerging drone technologies such as UAM and AAM, UTM, Digital Sky, and other enabling technologies
    - **Launch Civil UTM Development Programme**. The MoCA may launch an initiative to develop and deploy civil UTM through an iDEX Prime or ADITI competition equivalent programs of the MoD. The MoCA could seek the help of MoD, MeitY and National Aerospace Laboratory (NAL), to test and validate UTM and enabling technologies.
    - **Bring Synergy in Drone Technology Development**. The different ministries (MeitY, Ministry of Science and Technology, MoD, MoCA, etc), Departments (DST, etc.) and other entities may review the existing mechanism of R&D funding for academic institutions and incubation centres through various mechanisms to make them result-oriented.

- The DST may review the charter of NM-ICPS and include a roadmap for development of crucial drone and aeronautics technologies and filling gaps in drone technology including through TIHs. The funding needs to be focused on filling specific UAV and aeronautics technologies gaps.

- The development partners may be provided funding on a competitive basis with allocation of funding in phases for spiral development. The success of technology / innovation initiatives should be measured in terms of operationalisation, commercialisation and procurement by users, and not in terms of prototype development.

- **Enhance Contribution Academia, CoE and Incubation Centres in Drone Technology Development**. The measures proposed to enhance contribution of academia, CoE and Incubation Centres in drone technology development are as follows:

- Streamline Contribution of Academia in Drone Technology Development. The academia needs to be oriented towards filling technology gaps and developing niche UAV technologies. Their contribution in developing and operationalising niche UAV technologies needs to be scientifically examined and validated. Suitable corrective actions need to be instituted to enhance their contribution in UAV technology development.

- Bring Focus of CoE and Incubation Centres on niche drone technologies and technology gaps. Each CoE and Incubation Centre should have at least one core area with India's TRL gaps and a roadmap. At least three CoEs should be dedicated to UAV structure design, propulsion systems and payloads. Their funding should focus on developing niche technologies as well as filling specific technology gaps to strengthen indigenous design and manufacturing capabilities and reduce vulnerabilities.

- The products emerging out of funding for R&D, innovations and entrepreneurship to incubation centres, and CoE, start-ups, etc. by the DST, MeitY and other entities should be scientifically reviewed. The expertise and contribution of entities/ people involved in managing incubation centres and their ability to contribute in technology development, also needs to be examined to make these initiatives outcome and innovation-oriented.

- **Establish Aeronautical and Drone Technology University**. Establish a dedicated national aeronautical and drone technology university, with UAV & Next Generation Aircraft R&D centres, airfield, testing airspace and testing laboratories to advance indigenous design capabilities. This university would be a national university focused on developing niche technologies as well as filling specific technology gaps. It would undertake postgraduate, doctoral and post-doctoral specialised courses on drone and aviation technologies.

5. **Civil Drone Testing, Standards and Standardisation**. The measures needed to build a robust civil UAV development ecosystem comprising testing, standards and standardisation to transform the Indian civil drone manufacturing industry into an innovation-led manufacturing industry, are as follows:

   - **Accreditation and Availability of Laboratories**. The laboratories of the academic institutions, incubation centres, public sector entities, DRDO, DPSUs, defence forces and other institutions, should obtain NABL and other accreditations. These laboratories may collaborate with the private sector to make them available 24 hours a day, 7 days a week and 365 days a year.

   - **Formulate Policy on Archiving of Civil Drone Trials Data**. Creation of an archiving platform is recommended, where trials and testing data of civil drones, systems and sub-systems is stored for certification and standards formulation. This data would also be useful in formulating policies for future applications and integration of drones in Indian airspace.

   - **Create Civil Drone Testing Sites**. Civil drone testing sites need to be created with runways, testing laboratories and airspace to test long-range and high-altitude operation of fixed-wing drones.

- **Establish Civil Drone Corridors**. There is a need to designate civil drone testing and operation corridors to test and launch UAM, AAM, logistics supply, medical transportation by drones within the city, and inter-city operations.

- **Formulate Indian Civil Drone and Component Standards**. MoCA or the designed nodal ministry must be mandated and empowered to proactively formulate Indian civil drone and drone components standards to enhance quality of indigenously developed drones and components, reduce vulnerabilities and increase their acceptability in international markets.

- **Issue Standardisation Guidelines**. MoCA or nodal ministry in collaboration with industry may issue guidelines on standardisation of drones, components, sensors, payloads, software, materials, etc.

- **Launch Indigenous Drone Technology Validation Trials**. Launch indigenous drone technology validation initiatives for testing and trials of technologies being developed by Indian industry and academia.

6. **Civil Drone Certification Reforms.** The proposed reforms in certification of UAVs and technicians to develop and certify niche and innovative drones and components are deliberated below.

- **Formulate Policy on Certification of Civil UAVs >500 Kg**. MoCA should formulate a policy for certifications of civil UAVs weighing more than 500 kg.

- **Formulate Policy on Certification of Drone Components**. MoCA should formulate a policy on certification of drone components, materials, software, sensors, and payloads, etc. to support and encourage indigenous design of critical systems, sub-systems and sub-assemblies.

- **Introduce Policy on Trials Based Certification**. The DGCA could create provision in CUAS policy to undertake certification based on trials and testing of emerging, new and niche drone technologies, sub-systems, sensors and payloads developed by the Indian drone industry.

- **Reform BIS Battery Certification Policy**. The BIS adopts a trial-based drone battery certification policy to certify innovative and emerging battery technologies.

- **Introduce Civil Drone Technician Certification Policy**. Introduce a Drone Technician Certification Policy for drones weighing more than 500 kg taking into consideration the recommendation given in the article: "Reforms in Indian Aviation/ Drone Technician Certification Policy."[143] The current practice of training technicians by drone companies developing drones less than 500 kg, can continue.

7. **Demand Creation for Indigenous UAVs and Components**. The following is proposed to create demand and support indigenous design, innovation and IP creation:

- **Create IDDM/ iDEX Vertical in GeM**. Create 'Indigenously Designed Products (including UAVs)' vertical in Government e-Marketplace (GeM). The indigenously designed/ developed products can be further classified into the following:

  (i) Products developed under iDEX/ ADITI/ TDF/ Mehar Baba

  (ii) IDDM products including those developed under Make-I, Make-II and other provisions.

- **Enabling GFR Provisions**. The Ministry of Finance may introduce enabling provisions in the General Financial Rules (GFR) that give preference to indigenously developed UAV and products with indigenous content in procurement. All other ministries should implement this.

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[143] "Reforms in Indian Aviation/ Drone Technician Certification Policy", MP-IDSA Issue Brief, Manohar Parrikar Institute for Defence Studies and Analyses, 31 October 2023 at https://idsa.in/issuebrief/indian-aviation-drone-technician-certification-policy-rknarang-311023 (Accessed on 31 August 2024).

- **Positive Indigenisation List**. All ministries should examine promulgation and adoption of the Positive Indigenisation List especially on UAVs and systems on the lines of the MoD to support the Drone Hub 2030 mission.

8. **Enhancing Contribution of Private Sector and Industry Bodies**. The industry bodies and private sector companies can play a greater role in supporting indigenous design, development, manufacturing, and export of Indigenous UAVs and systems, and integration of drones in Indian airspace.

   - **Private-Private Partnerships**. For integrating MSMEs into the defence ecosystem, large corporations like Tata, L&T, Godrej, etc. need to have greater collaborations and offset partnerships with the MSMEs and start-ups. Similarly, drone integrators should hand-hold Indian drone components, materials, sensors, payloads and software manufacturers, to support deign in India.

   - **Private Sector Investment in R&D**. The private sector should enhance R&D funding for creating Intellectual Property Rights (IPRs) and support *atmanirbharta*.

   - **Private Sector and Industry Bodies in Ecosystem Creation**. Indian drone and other industry bodies, and private sector companies need to review their approach and become partners in the creation of a technology development and innovation ecosystem. They should take the lead and participate in technology validation and operationalisation initiatives, creation of Indian standards, standardisation guidelines, testing facilities, world-class design and manufacturing and export ecosystem in India.

9. **BVLOS Operations Policy**. DGCA promulgated the Beyond Visual Line of Sight (BVLOS) operations policy, for which trials have already been completed.

Course Corrections in Defence UAV Sector

India has significant in-house capability to develop UAVs and sub-systems indigenously, which needs to be optimised with suitable course corrections. The course corrections would include, but not remain limited to, adequate allocation of funds, greater involvement of users and placing trust in indigenous developers, to fill the gaps and make indigenous defence UAV development programmes a success. Making production entities and users members of development projects as partners with a share of funding would be crucial for enhancing the potential of success in indigenous development projects.

Indian defence UAV development programmes faced challenges due to lack of coherence, synergy, ownership, accountability and dispersal of responsibilities. The lack of technical review of closed projects, lack of technical experts having an understanding of user requirements in DRDO and DPSUs, absence of a roadmap with timelines, stakeholders and funding for UCAV, HALE, CATS and RUAV programmes,limitations and challenges of DcPP, and the role of defence forces in design and development of UAVs, are some of the critical issues that need to be addressed to overcome limitations and make indigenous defence UAV projects a success. The measures needed to vitalise indigenous defence UAV development programmes are deliberated below.

1. **Defence UAV Policy Reforms for Atmanirbharta**. The policy reforms aim to stimulate and elevate the defence UAV technology development trajectory in India. Some of the policy and structural reforms proposed in this section are not only related to UAVs but also to defence technology development in general. The proposed defence UAV policy reforms are as follows:

    - **Formulate Indigenously Designed and Developed Certification (IDDC) Policy**. Introduce Defence IDDC policy that includes UAVs and aviation. An independent designated technical body could be authorised for providing IDDC to defence UAV/ aviation platforms, sensors, payloads, software, etc. designed and developed by Indian industry.

    - **IPR and Data Protection**. Introduce mechanisms in the airworthiness and IDDM certification policies to ensure protection and safety of data and IPRs of UAV and sub-system manufacturers.

- **Defence Design Organisation Approval for Start-Ups**. CEMILAC, DGQA, suitable entities of the DPSUs, defence forces or an independent designated technical entity may accord design organisations approvals to start-ups and MSMEs involved in developing defence products through iDEX, Mehar Baba, TDF and other technology development initiatives. The mechanism may also be created for gradation of start-ups and MSMEs to bring standardisation in design and QA.

- **Defence Design Organisation Gradation Policy**. Create a design organisation gradation policy to differentiate design capabilities of defence sector start-ups and MSMEs.

- **Indigenous Content Definition.** CEMILAC or any other technical body may be authorised to define the percentage of IC for UAVs based on its sub-systems, components, software, materials, sensors, payloads, etc. It may also define standards for IC percentage of IDDM UAVs based on materials, software sensors and payloads.

- **Indigenous Content Validation in IDDM & ToT**. Formulate policy and create structures in CEMILAC, or other independent designated technical entities for technical verification of indigenous content (IC) of products manufactured in India under the IDDM as well as on ToT from foreign OEMs. The IC should be assessed in terms of materials, components, and software.

- **Policy on Archiving of Indigenous Designs**. The DRDO, Department of Defence Production (DDP), CSIR and other entities may formulate policies on archiving designs of indigenous technologies, products, software, etc. developed by DRDO, DPSUs, CSIR laboratories and other organisations, with suitable provision for protection of IPRs and safety of designs and data to ensure that past knowledge is suitably preserved and can be used for future designs, design improvements and learnings.

- **Spiral Development Policy**. The MoD / DRDO may introduce a spiral development projects policy. The need for consent of users to approve funding for spiral development projects should be reviewed. If required, an independent expert committee having representatives from DRDO, users, academia and domain experts, be formed for professional screening and expeditious approval of spiral development projects.

- **Post Induction Design Improvement Projects**. The feedback on the performance of systems and subsystems after their induction into operational service should be leveraged, to launch upgraded projects to improve their designs, manufacturing and maintenance processes of UAVs, systems, sensors, payloads, software etc.

- **Rationalising Foreign Procurements**. The procurement of MALE, HALE and other UAVs from foreign OEMs would create an inventory for about 40 years. This in turn would make indigenous UAV development programmes unviable as in the case of *Marut* fighter aircraft. Therefore, procurement of MALE, HALE and other UAVs may be restricted and rationalised in a manner that the limited procurement allows meeting the bare essential operational requirements. However, these procurements should not be so large that indigenous projects become unviable. Therefore, if required, limited number of UAVs may be taken on lease for a short duration to provide interim solutions.

2. **Defence UAV Structural Reforms**. The structural reforms needed to stimulate indigenous design and make indigenous development projects a success, are given below.

- **Creating R&D Structures in DMA and HQ IDS**: Establish Military science and technology vertical under a Joint Secretary level officer in the Department of Military Affairs (DMA) at MoD with the responsibility of progressing military S&T, *atmanirbhata* in military technologies, synergy with industry and MCTF.

  Establish a Directorate of Science, Technology, Research and Development, and innovation (STRDI) in Headquarters

Integrated Defence Staff (HQ IDS) to support and become a stakeholder in design and development of defence technologies including UAVs, being undertaken by the DRDO, DPSUs and private sector. It would also bring synergy in R&D, indigenous development and innovation projects.

- **Creating R&D Structures in Defence Forces**. The three Services may enhance the scope of their Design Directorates and Bureaus and establish R&D verticals on the lines of AFRL, ONR, Army Innovation Command and Army Futures of Command (AFC) of the US and corresponding formations of the Peoples' Republic Army (PLA) of China. The size of such an organisation manned by highly qualified defence personnel with required technical expertise and competency to become members of design teams undertaken by DRDO, DPSUs and industry, however, would be small.

- **Including Users in Design Teams**. The participation of Indian Defence Forces should be enhanced from testing and review to design and development. The qualified defence technical personnel need to become members of the design teams for UAV, UCAV, CATS and HAPS programmes in a manner similar to AFRL, ONR and Army Research Laboratory of the US defence forces and the People's Liberation Army (PLA), to provide inputs to designers, right from the initial phase onwards.

- **Reviewing Career Profile of Defence Forces Personnel**. The career profiles of technically qualified defence forces personnel involved in indigenous design and development projects, may be suitably modified to accommodate their participation as members of design and development teams and have longer tenures. The tenures and career profiles of Army and Air Force personnel can be similar to the tenures and career profiles of personnel of the Navy.

- **Induction of Test Pilots and Test Engineers by DRDO and NAL**. DRDO and NAL may consider induction of flight test pilots and flight test engineers to fill the gaps between operational requirements of users and their products.

3. **Streamlining UAV R&D and Technology Development**. The measures proposed to streamline UAV R&D and technology development are given below:

   - **Empowering Project Team**: The project team comprising developers, manufactures, users and certification agencies, must be independent and flexible to implement mid-course correction without a time-consuming approval process.

   - **Realistic Timelines**: A key lesson from the *Rustom 2* (*Tapas*) project is to have a realistic timeline. Therefore, developers, manufacturers and users should carry out realistic assessments and work out reasonable development timelines for D&D projects.

   - **Realistic QRs**: The QRs should be rational and realistic, based on available technologies, funding and operational requirements. The QRs should follow an escalation matrix to support spiral development and enhance chances of success of indigenous UAV development programmes.

   - **Accountability of Stakeholders**: The accountability of stakeholders contributing to delays and failures in indigenous programmes needs to be fixed. The respective stakeholder may be made to pay for increase in costs of development caused by their unrealistic demands and unreasonable actions/ inaction, similar to the one-responsibility principle followed by the Directorate General of Armament (DGA) of France.[144]

   - **Simplification of the Approval Process**: Approval for funding of each project is sought in advance at each stage. The follow-up on administrative control and audit mechanism needs to be reformed, rationalised and simplified.

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[144] "Responsibility Principle", Committee of Experts for Amendments to DPP-2013 Including Formulation of Policy Framework, 23 July 2015, p.199 at https://www.mod.gov.in/dod/sites/default/files/Reportddp.pdf (Accessed on 19 June 2024).

- **Funding by Users**. The provision of funding by users in indigenous development projects must be examined.

4. **Streamlining Defence UAV Projects.** The following measures are proposed to overcome challenges and limitations, and propose a roadmap for defence UAV development projects:

   - **SRUAV**: The MoD may form a technical committee to analyse capabilities and challenges of SRUAV and create a roadmap for its operationalisation. The Army and the CAPF, as potential users of the SRUAV, could join as development partners so that the gaps between current capabilities and requirements of users can be addressed.

   - **MALE UAV**: The MoD may undertake technical review of the *Tapas* Medium-Altitude Long-Endurance (MALE) UAV programme, including technologies and systems developed in the project. Examination of the synergy between development and production agencies, is necessary, as is rationality / viability of achieving QRs in the *Tapas* UAV project. Accordingly, institute corrective measures and leverage these technologies for expediting the development of armed Archer MALE UAV in a time-bound manner with the participation of users and production entities as development partners.

   - **HALE**: Analyse the need and chalk out a roadmap for indigenous development of the HALE UAV. The stealth or semi-stealth jet engine HALE UAV configuration could be examined for higher altitude, higher speed and enhancing survivability.

   - **RPSA (UCAV)**: The completion of SWIFT trials and approval of RPSA with funding, development timelines and user participation should be expedited.

   - **Kaveri Aero Engine**: Accelerate testing of non-afterburner *Kaveri* turbojet engine at high-altitude and on the airborne test platform (test aircraft). The development of *Kaveri* should be synergised with the RPSA programme. The DRDO, in consultation with the Air Force, could examine the need for developing a turbofan variant of *Kaveri* with higher efficiency and endurance for the HALE platform.

- **CATS**: The Air Force and HAL should create a concept of operations, PSQRs, a roadmap and timeline for the development of CATS. The Air Force, with its experience of aircraft testing, should be involved in the development and certification of aeroengine for the CATS *Warrior* and data link, which are at the core of CATS programme.

- **HAPS**: HAPS would require development of several enabling technologies, sensors, data links, etc. Therefore, it would be prudent that NAL and NSRT identify complementarities in technologies and prevent unwarranted duplication. They need to work in tandem to develop full scale HAPS indigenously for civil-military applications for the Indian and global market.

- **Unmanned/ Optionally Manned Stealth Bomber**: Feasibility studies need to be undertaken for developing twin-engine stealth flying wing unmanned or optionally manned long range bombers to undertake deep penetration strike missions. The feasibility studires could also examine the development of larger unmanned or optionally manned versions (Mark-II) of the Advanced Medium Combat Aircraft (AMCA) for the stealth bomber's role.

- **Sixth-Generation UAV**: A feasibility study for developing unmanned or optionally manned platforms needs to be carried out with Sixth-Generation technologies to create a roadmap for developing future UAVs or introducing these technologies in ongoing projects.

- **Unmanned Helicopter**: Expedite RUAV-200 unmanned helicopter certification and take measures for its induction. If required, private sector entities can be involved to fill the technology and capability gaps. The Army and Navy could join the project as development partners to fill the gaps between prototype and user requirements. The need for building its armed variant may also be examined.

- **Light Weight Airframes/ Structures**: The development of high-strength carbon fibre airframe/ structures through indigenous production or transfer of technology (ToT) can be examined to strengthen the indigenous UAV and manned aircraft development programmes. Newer methods of production that are out of Autoclave composite manufacturing processes such as VA-RIM technology can be adopted to manufacture high-quality cost-effective airframes in India.

- **Self-Reliance in Components, Systems and Sub-Systems**: Programmes for designing and manufacturing components and subsystems including aero-engines, secure communication networks, electronics hardware, software, magnets, sensors and payloads should be launched to prevent unwarranted dependencies, cyber-attacks, data theft and other vulnerabilities. Also advanced technologies like Artificial Intelligence should be incorporated in analysis and other emerging applications.

- **Indigenous Content Roadmap**: A roadmap for increasing the IC based on major sub-systems, materials, software and components of indigenously developed UAVs as well as those manufactured under ToT and Joint development projects, should be formulated.

- **iDEX Core**. Launch special iDEX Core competition to develop indigenous critical and vulnerable components, subsystems, software, sensors, payloads such as propulsion systems, software defined radios, data links, battery cells, networks, etc. that may not be a whole product by itself but are essential for security, supply chain resilience, for developing indigenous variants or for upgrades of a systems or equipment. iDEX Core may be launched concurrently with the other (main) iDEX/ ADITI/ TDF projects.[145]

[145] The idea for developing core critical technologies through special iDEX initiative that could be named as iDEX core was suggested by Shri Sai Pattabiram from Zuppa Geo Navigation Systems Pvt Ltd, Chennai to the author

- **Military UTM.** The development of Military UTM under the iDEX Prime or ADITI scheme is recommended with the following details
    - Development of military UTM with secure real time detection and tracking system for small drones.
    - Integrate military UTM with Air Traffic and Air Defence network of the IAF.
    - Military UTM be interoperable with UTMs of IA, IN, CAPFs, civil UTMs and civil ATC.

5. **Defence UAV Testing, Standards and Standardisation**. The way forward for reforming, re-orientating and expanding the defence UAV technology development ecosystem comprising testing, standards and standardisation, is as follows:

- **Advanced Testing Facilities**: The R&D testing facilities such as high- altitude and supersonic wind tunnels, test aircraft and other facilities for supporting indigenous development of UAVs, aeroengines and other technologies, must be built for achieving self-reliance in aeronautics and UAV technologies including aeroengines.

- **Indian Standards for Defence UAVs and Components**: Formulate Indian standards for defence UAVs and critical components to facilitate inter-operability and reduce vulnerabilities.

- **Fixed-Wing UAV Test Sites**: Establish defence UAV testing sites (Fixed-Wing) with suitable ground systems and adequate airspace for the private sector under the DTIS or other schemes, as deemed appropriate.

- **Standardisation in UAV User Trials/ Demonstrations**: Formulate a policy or mechanism for standardisation in trials and demonstration of UAVs. The results of such trials should be acceptable to the arms and services of the Army, Air Force, Navy and CAPFs, to optimise utilisation of resources and reduce financial burden on manufacturers.

- Similarly, DMA may formulate policy to standardise defence equipment trials/performance demonstrations to reduce repetitive trials and demonstrations by various formations within the organisation or by different organisations within the MoD, to reduce burden on industry especially starts-ups and MSMEs. The MoD and MHA may formulate mechanisms to accept each other's trial reports as far as possible.

6. **Defence Certification and Quality Assurance (QA) Reforms**. The defence certification and quality assurance reforms are outlined below:

   - **Establish Defence Certification and QA Organisation**: Establish Defence Certification and Quality Assurance (DCQA) as an independent and autonomous body. Place CEMILAC and DGAQA under DCQA. Similarly, Director General of Quality Assurance (DGQA), Directorate of Naval Quality Assurance of DGQA, Centre for Fire Explosive and Environment Safety (CFEES) and Scientific Analysis Group (SAG)[146] should be placed under the DCQA.

   - **Delegation of Airworthiness and QA Certification**: Entities like Regional Centres of Military Airworthiness (RCMA) of CEMILAC, Base Repair Depots (BRDs) and Software Development Institute (SDI) of the Air Force, similar formations of the defence forces, DPSUs and other suitable entities should be given powers for Airworthiness and QA certification depending on their expertise.

   - **Certification of Testing and Certification Bodies**: The independent designated technical entity may evolve a system of "Certifying Testing and Certification Bodies" to offload their work.

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[146] Scientific Analysis Group (SAG) at https://www.drdo.gov.in/drdo/labs-and-establishments/scientific-analysis-group-sag (Accessed on 2 June 2024).

- **Civil-Military UAV Certification Synergy**: CEMILAC/independent designated entity of the defence sector should recognise IDDM certification issued for UAVs by DGCA and vice-versa.

7. **Defence Procurement Reforms for *Atmanirbharta***. The reforms in defence procurement procedures to promote and support *atmanirbharta* in defence technology (including UAV) design, development, manufacturing and export are given below:

    - **Development Production User (DPU) Partnership**: Review and replace the Development-cum-Production Partnership (DcPP) Scheme with the DPU Scheme in Defence Acquisition Procedure (DAP) to overcome current limitations. The inclusion of users as development partners would expedite development and reduce failures.

    - **MoQ in DAP**: The MoD may have provision in DAP for procurement of Minimum Order Quantity (MoQ) for indigenously developed UAVs and systems developed through iDEX, ADITI, Mehar Baba Competition, Make-I and Make-II.

    - MOQ procurement of other indigenously designed products may also be examined.

    - **Introduce L1 T1 IC1**: The MoD may reform the L1 procurement model under the Defence Acquisition Procedures (DAP) to facilitate preferential procurement of indigenously designed equipment, as is being followed in the Brahmos and space programmes. The Low- Cost High-Technology (L1 T1)[147] or Low-Cost-High Technology and High-Indigenous Content (L1 T1 or IC1) procurement models should be followed to support procurement of indigenously designed products with high indigenous content.

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[147] "L1 versus T1 versus L1T1", Centre for Land Warfare Studies, 21 September 2013 at https://archive.claws.in/1080/l1-versus-t1-versus-l1-t1-sanjay-sethi.html (Accessed on 8 June 2024).

- **Positive Indigenisation List**: A Positive Indigenisation List for Drone Technologies for all Ministries may be promulgated. The critical and vulnerable drone components such as flight controllers, electronics speed controllers, motors, communication, data relay, data storage, etc. that are being developed by Indian companies must be placed in the Positive Indigenisation List. A suitable transition period may be given to allow Indian industry to develop such systems in India.

- **Below Par Bidding in Tenders**: The bidders deliberately quoting the price well below (say 20 per cent) the budgeted value in tenders should be rejected, to rule out unethical players and avoid unnecessary delays. They should be blacklisted and barred from participation in future projects if they deliberately and nefariously manipulate the prices to damage the indigenous manufacturing ecosystem.

8. **Collaborations and Partnerships**. The measures needed to leverage collaborations with global and Indian private sector entities to become *atmanirbhar* as well as for establishing mutually beneficial partnerships, are given below.

    - **Co-development and Co-production with Global Partners**: The emphasis of collaboration with foreign OEMs should be on co-development with joint Intellectual Property (IP) with focus on specific critical technology gaps that cannot be filled by Indian entities or require contribution from both partners. If required, production in both countries could be undertaken to meet the requirements of their respective domestic and global markets.

    - **Public-Private Partnership**: In future projects, DRDO may fix the preliminary design of UAVs and invite big Indian private sector companies to utilise the design in an optimal manner.

Chapter 6

Conclusion

The Indian civil-military drone industry is at the cusp of transformation to becoming a research, innovation and IP-led industry. The policy reforms in the civil drone industry since 2021 facilitated development of a wide variety of small drones and their adoption in various commercial applications. However, the impact of the civil drone policy reforms is reaching its limits. The further growth of the drone industry requires reforms in the civil drone technology segment comprising launching of drone technology development initiatives and nomination of a nodal ministry for UAVs that has R&D structures and takes the lead in the development of civil UAV technologies on the lines of the FAA (USA), EASA (Europe) and CAAC (China). There is a need to create a robust civil UAV technology development ecosystem comprising R&D programmes, establishing civil drone testing sites and testing corridors, mechanisms for trial-based standards formulationand articulation of standardisation guidelines in collaboration with the industry.

The articulation of the indigenous design certification policy and designation of the nodal agency to provide the Indigenously Designed and Developed Certificate (IDDC) is needed to facilitate accreditation of UAVs designed and developed by Indian companies. The recent amendment in the Defence Acquisition Procedure (DAP) to certify Indigenous Content (IC) based on materials, components and software needs to be adopted by all ministries. The implementation of IC assessment needs to be based on scientific assessment to encourage indigenous design and development of UAVs. The IC validation based on materials, components and software of both IDDM products as well as products manufactured under ToT, would bring clarity in the technology development trajectory and make a significant contribution to *atmanirbharta*.

The reorientation and reforms in DST, Meity and MoD-sponsored funding programmes for start-ups and academia is needed. Introducing focused UAV technology development initiatives is essential to address critical UAV technology gaps and minimise duplication in R&D. The proposed certification and procurement policy reforms to support indigenous design, development and manufacturing can significantly enhance the growth of the Indian UAV manufacturing industry.

India's indigenous defence UAV development programmes are at a crucial phase and there is a need to introduce measures to identify challenges and institute course corrections for early operationalisation of large UAVs. The technical review of SRUAV and *Tapas* MALE UAVs, expediting development of *Archer-NG,* launch of the indigenous HALE UAV development plan, finalisation and approval of RPSA and CATS, and completion of the non-after burner *Kaveri* engine certification, are critical for *atmanirbharta* in defence UAVs. The indigenous development of niche and innovative UAVs with indigenous systems, sensors and payloads, needs dedicated funding, time-bound execution, autonomy with accountability of project leaders, synergy among stakeholders and greater investment in R&D by both the public and private sectors.

India's defence UAV technology development initiatives need to be complemented with the corresponding civil UAV technology development initiatives. India's aim of becoming the UAV technology hub would require formulation of the MCTF policy and creation of MCTF structures. The launching of MCTF initiatives that transcend boundaries between civil and military UAV industries, are essential for optimally leveraging common testing resources, reducing infrastructure investment and building a high-value globally competitive UAV industry.

The research findings, deliberations and the way forward in the Monograph validate the hypothesis that the Indian drone industry, led by start-ups and MSMEs, has the potential to transform into an innovation and IP-led high- technology high-value industry in India. Indian innovators have already demonstrated this with the development of niche swarm, loitering, logistics supply and other UAV technologies. The second hypothesis that fusion between civil and defence UAV industries, nomination of nodal ministry, formulation of *atmanirbharta* policy, creation of R&D structures and an enabling ecosystem and self-reliance in critical technologies are essential for India becoming the global drone hub@2030, is plausible but can only be validated after the initiation of reforms by the government.

The Indian UAV sector requires major reforms to bridge the gap between potential and current capability. The reforms need to address critical policy, structural and ecosystem gaps. The ownership, MCTF, creation of a civil drone technology development ecosystem and course corrections in military drone technology development programmes, are essential to make India a *Anusandhan se Atmanirhbar* Global Drone Hub by 2030.

Appendix "A"

Drones Components Development by the Indian Private Companies

The details of Indian companies that have undertaken design, development and manufacturing of various drone components are given below.

1. **Agam Robotics**. Agam robotics is developing autopilot, Electronics Speed Controllers (ESC), Optical Flow Sensor and GPS/ GNSS and Digital Power Modules.[148]

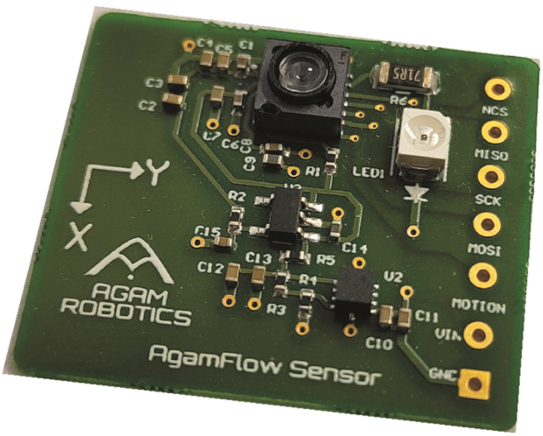

Fig 10, Optical Flow Sensor, courtesy Agam Robotics

[148] Agma Robotics at https://www.agamrobotics.com/ (Accessed on 1 September 2024).

2. **Reflex Drive**. Reflex drive is developing Propellers, BLDC Motors, Electronics Speed Controllers (ESC), Power Distribution Board and Capacitor Banks.[149]

Fig.11. BLDC Motors, courtesy Reflex Drive

Fig.11A. Electronics Speed Controller (ESC), courtesy Reflex Drive

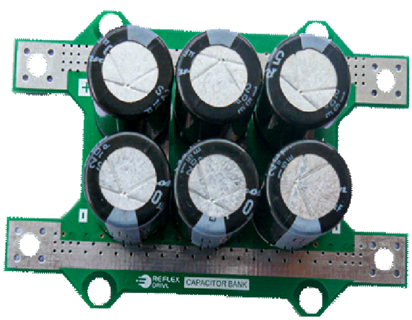

Fig.11B. Capacitor Bank, courtesy Reflex Drive

[149] Reflex Drive zat https://reflexdrive.in/ (Accessed on 1 September 2024).

3. **Zuppa Geo Navigation Technologies Private Limited**. Zuppa has developed an autiopilot, laser designator module, suraksha firewall module and GPS module.[150]

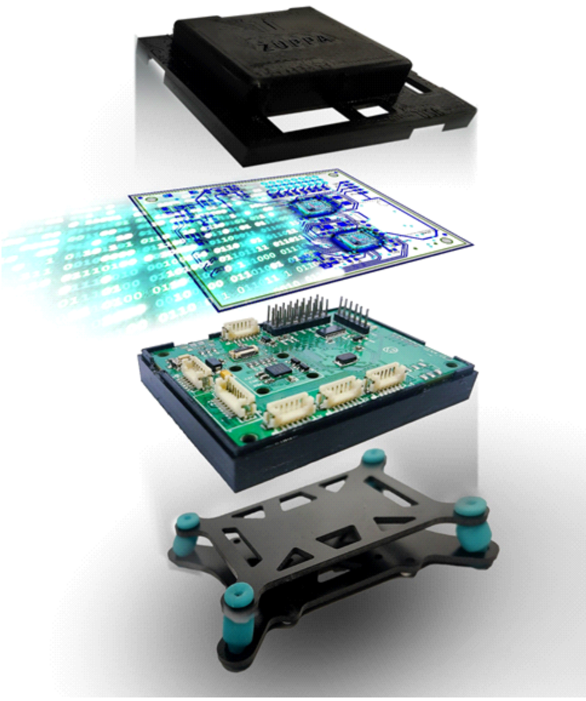

Fig 12.Navgati, Autopilot, courtesy, Zuppa Geo Navigation Technologies Pvt Ltd.

150 Zuppa Geo Navigation Technologies Private Limited at https://www.zuppagps.com/ (Accessed on 1 September 2024).

4. **Zeus Numerix**. Zeus numerix has collaborated with a Public Sector Unit to develop miniaturised bombs for drones.[151]

Fig13 . Light Weight Bomb, courtesy Zeus Numerix

151 Zeus Numerix at https://zeusnumerix.com/index.html (Accessed on 1 September 2024).

5. **Vector Tachnics**. Vector technics is developing BLDC motors, ESC, Start Generators, Propellers, Power Distribution Boards and DC-DC Converters.[152]

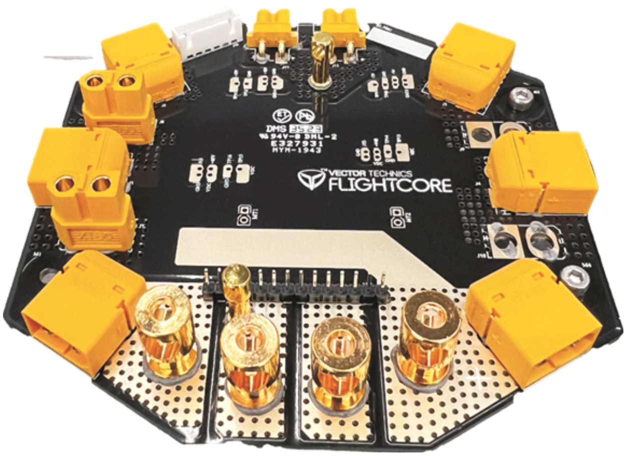

Fig 14. Power Distribution Board (PDB), courtesy Vector Technics.

6. **Nautical Wings Aerospace**. Nautical Wings Aerospace is developing propellers and axial motors.[153]

7. **Welkinrim Technologies.** Welkinrim Technologies is developing Electronics Speed Controllers (ESC), Integrated Power Systems, Motors and Autopilot.[154]

8. **Elena Geo Systems**. Elena Geo System Pvt Ltd. has developed Multi GNSS Processor, Muti GNSS module, GNSS Antenna, GNSS Receiver and Drone Navigation system.[155]

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152 Vector Technics at https://vectortechnics.com/?srsltid=AfmBOoqLhiFihb8GEaG1NubebJfxpvAfKnQtIEvSfmxdd5EbseHvHxQU (Accessed on 1 September 2024).

153 Nautical Wings Aerospace at https://nauticalwings.com/ (Accessed on 1 September 2024).

154 Welkinrim Technologies at https://welkinrim.com/services.html (Accessed on 1 September 2024).

155 Elena Geo Systems Pvt Ltd, https://elenageosystems.com/static/media/ElenaNDNUv3.60422261.pdf, accessed on 20 September 2024

Appendix "B"

Drones Development by the Indian Private and Public Sector Companies

The details of indigenous drones developed by the Indian private industry that were inducted or are in the process of being developed for commercial and defence applications include:

1. **New Space Research and Technologies (NSRT).**[156] NSRT is developing niche and innovative drones, drone swarms and High-Altitude Pseudo Satellites (HAPS). It is a winner of iDEX competitions. It signed a deal to supply 130 tethered drones to the Indian Army.[157] In addition, it has developed Swarm UAVs..

Fig 15. Swarm UAVs, courtesy New Space Research Technology

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[156] New Space Research and Technologies at https://newspace.co.in/ (Accessed on 1 September 2024).

[157] Dinkar Peri, "Army signs deals for 130 tethered drones and 19 tank driving simulators", *The Hindu*, 29 August 2023 at https://www.thehindu.com/news/national/army-signs-deals-for-130-tethered-drones-and-19-tank-driving-simulators/article67248535.ece (Accessed on 21 June 2024).

2. **Kadet Defence Systems.**[158] Kadet Defence System collaborated with the DRDO to develop the Loitering Aerial Munition (LAM) UAV.[159] It signed a contract to supply 50 LAM Kamikaze drones.[160]

Fig 16. Loitering Aerial Munition (LAM) Kamikaze Drone, courtesy, Kadet Defence Systems

3. **ePlane.** ePlane is developing drones for urban air mobility.[161]

Fig 17. E-50 Electric drone, courtesy ePlane

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158 Kadet Defence Systems at http://www.kadet-uav.com/ (Accessed on 1 September 2024).

159 Sanjib Kr Baruah, "India's first kamikaze drone developed; 5000 units can be made in 203 years", 8 May 2024 at https://www.theweek.in/news/india/2024/05/08/indias-first-kamikaze-drone-developed-5000-units-can-be-made-in-2-3-yrs.html (Accessed on 22 May 2024).

160 "Kadet Defence Systems introduces India's pioneering Loitering Aerial Munitions (LAMs) for the armed forces", *Financial Express*, 8 May 2024 at https://www.financialexpress.com/business/defence-kadet-defence-systems-introduces-indias-pioneering-loitering-aerial-munitions-lam-for-the-armed-forces-3481405/(Accessed on 3 July 2024).

161 ePlane at https://www.eplane.ai/ (Accessed on 1 September 2024).

4. **Cingularity Aerospace.**[162] Cingualrity has developed a tandem low altitude long endurance drones and jet engine expandable target drones.

Fig 18. Tandem Wing Low Altitude Long Endurance Tactical UAV, courtesy Cinguarity Aerospace

Fig 18A. Jet Engine High Speed Expandable Target Drone, courtesy, Cingularity Aeropspace.

[162] Cingularity Aerospace at https://www.cingularity.in/ (Accessed on 1 September 2024).

5. Z**uppa Geo Navigation Technologies Private Limited.** Zuppa has developed a small drones for training and ISR roles.[163]

6. **ideaForge**. IdeaForge has developed a switchblade UAV, which is essentially a surveillance multi rotor UAVs with a wing for optimal performance with vertical take-off and forward flight. It supplied 200 Switch Vertical Take-Off and landing (VTOL) UAVs to the Indian Army.

7. **Economic Explosives Ltd (EEL).** 480 *Nagastra-1* man portable precision strike loitering drones were procured by Indian Army from Economic Explosives Ltd (EEL), a subsidiary of Solar Industries.[164]

8. **Aayan Autonomous Systems.** Aayan Autonomous Systems had developed intelligent UAVs including swarm UAVs and is finalist of Mehar Baba UAV competition-II of the IAF.[165]

9. **Enord**. Enord has developed intelligent drone named Inspector lite.[166]

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163 Zuppa Geo Navigation Technologies Private Limited at https://www.zuppagps.com/ (Accessed on 1 September 2024).

164 Manjeet Negi, "Army gets *Nagastra-1*, India's first indigenous suicide drone", *India Today*, 14 June 2024 at https://www.indiatoday.in/india/story/indian-army-nagasatra-1-first-indigenous-suicide-drone-defence-technology-2553109-2024-06-14 (Accessed on 22 June 2024).

165 Aayan Autonomous Systems at http://www.ayaan.ai/ (Accessed on 1 September 2024).

166 enord, https://enord.co/ (Accessed on 20 September 2024).

10. **HAL.** HAL is developing RUAV 200 unmanned helicopter for various defence applications.

Fig 19. RUAV 200, HAL, courtesy author

This monograph examines civil and military drone policies, organisational structures, technology development initiatives, ecosystems, strengths, challenges, and proposes a way forward. It recommends formulating a civil drone atmanirbharta policy, designating nodal ministry of drone technology, creating organisational structures for civil drone R&D, launching civil drone technology development initiatives and instituting course corrections in defence UAV development programs. It also emphasises that academia, Incubation Centres, private sector, public sector and users need to focus on filling drone technology gaps. It advocates creation of robust ecosystem comprising trial based certification, civil drone testing facilities, formulation of Indian standards, and standardisation guidelines in drones. It lays emphasis on atmanirbharta in critical drone technologies, sensors & payloads; creating indigenous design and Indigenous Content (IC) certification mechanisms, indigenously designed and iDEX products vertical in GeM and promulgating Design Linked Incentive (DLI) Scheme. Most importantly, it proposes formulation of military-civil technology fusion (MTCF) policy for making India atmanirbhar global drone hub@2030.

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He authored a book titled "India's Quest for UAVs and Challenges", HQ IDS-SIDM report titled "A Roadmap for India Becoming Atmanirbhar in Counter Drone Technologies/ Systems" in 2022 and research papers on aviation, drones, Make in India and Self-Reliance. He was a member of Drone Working Sub Group, Department of Industry and Internal Trade (DPIIT) in 2020-21, High Power Steering Committees (HPSC) of Innovation for Defence Excellence (iDEX) in 2021-22 and Study Group on Drones set up by NSCS in 2022-23; and participated in track-1.5 and track-2 dialogues.

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