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UNMANNED AIRCRAFT SYSTEM TRAFFIC MANAGEMENT (UTM): POLICY, ROADMAP AND THE WAY FORWARD

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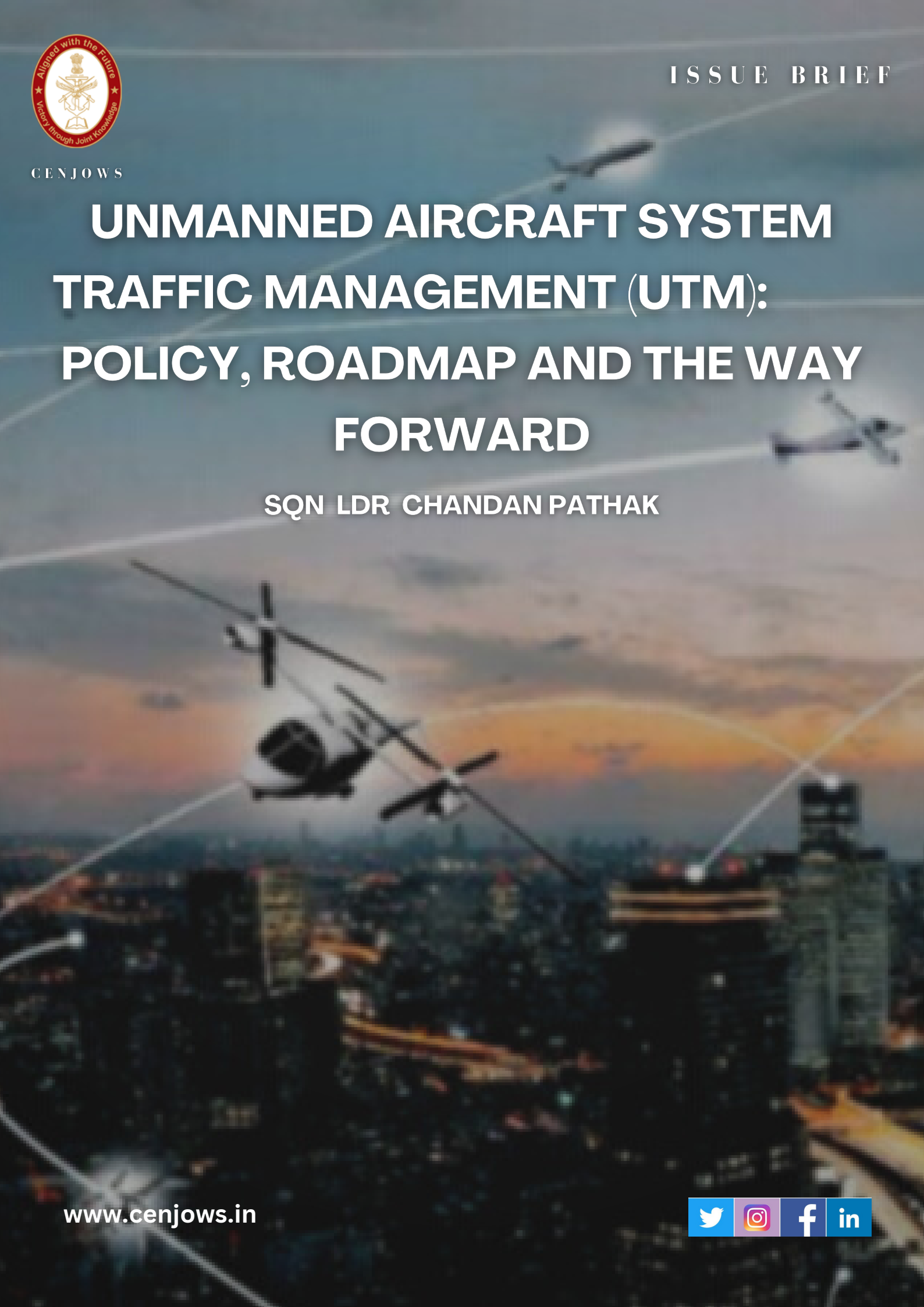

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UNMANNED AIRCRAFT SYSTEM TRAFFIC MANAGEMENT (UTM): POLICY, ROADMAP AND THE WAY FORWARD

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"Do not fly too close to the sun"

\- *Daedalus*

Abstract

Unmanned Aircraft System Traffic Management (UTM) is an architecture for safely and efficiently integrating large-scale small unmanned aircraft systems (sUAS) operations in low-altitude airspace. This paper outlines a comprehensive roadmap for the IAF in taking a proactive role in UTM implementation, signifying the advantages it brings to the Indian Armed Forces and the nation as a whole. It highlights the crucial role of Remote ID in ensuring the safe and efficient integration of unmanned aircraft systems (UAS) into the national airspace. It discusses the need for robust technological infrastructure, a comprehensive policy framework, and comparisons with other countries that can serve as a reverse-engineered roadmap for UTM implementation. Additionally, it proposes the DIAD model for countering UAS threats and integrating UTM capabilities. The paper also discusses the essential skill sets and training required for armed forces personnel in UTM sustenance and management. By actively engaging in UTM implementation, the IAF can enhance its operational capabilities, contribute to national security and position itself as a leader in adopting advanced aerospace technologies in line with the Indian Air Force Doctrine and our National Security Objectives.

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Introduction

The global drone market will grow from $14 billion in 2018 to over $43 billion in 2024 at a CAGR of 20.5%[1]. India is one of the fastest growing drone markets in the world, having increased in size exponentially since legalisation of drones in 2018. In 2021, the drone service market in India was valued at 183 million dollars. It was expected to reach over four billion dollars in 2030, growing at a compound annual growth rate of 44 percent[2].

Given the number, type, and duration of UAS operations envisioned, the existing Air Traffic Management (**"ATM"**) system infrastructure and associated resources cannot cost-effectively scale to deliver services for UAS. The current ATM system architecture does not cater for unmanned aircraft. Integration of unmanned aircraft in the Indian airspace using conventional means would result in expensive and bulky hardware, which is neither feasible nor advisable. This requires the creation of a separate, modern, primarily software-based, automated UAS Traffic Management (UTM) system. Such systems may subsequently be integrated into traditional ATM systems.

With this aim in mind, The National Unmanned Aircraft System Traffic Management (**"UTM"**) policy framework was released in Oct 2021, by the Ministry of Civil Aviation[3]. As per the policy guidelines, the UTM architecture allows for the sharing of the identity and location of the unmanned aircraft with other airspace owners and people on the ground. This provides stakeholders with situational awareness and on the other side also enables law enforcement and security agencies to track unmanned aircraft when necessary.

While the Indian Air Force in its latest revised doctrine aspires to be an Aerospace Force, there is a more complex, rapidly rising, high density and unregulated traffic in the very low-level airspace (up to 1000 ft above ground level) that needs immediate attention. There is a continuous need to develop and mature a Concept of Operations (**"ConOps"**)[4] for UTM at Very Low Level Airspace (**"VLL"**) airspace led by the Indian Air Force in conjunction with DGCA.

The Indian Air Force Should Lead The Way In UTM Implementation:

Responsible for safeguarding the nation's airspace, the IAF's role in UTM implementation goes beyond airspace management.

(a) *Enhanced airspace management and improved situational awareness*: By leveraging UTM technologies like flight planning, airspace authorization, and real-time tracking, the IAF can streamline and automate processes that were traditionally resource-intensive, reducing the burden on air traffic controllers and improve operational efficiency. Integration with integrated surveillance systems, such as Integrated Air Command and Control System (**"IACCS"**) would enhance the composite situational awareness, enabling early warning and response to unauthorized Unmanned Aircraft System (**"UAS"**) incursions.

(b) *Border Surveillance and Disaster Management Capabilities*: The rapid growth curve of UAS also poses challenges in terms of airspace security, unauthorized intrusions, and potential threats to critical infrastructure. The disruption caused by unauthorized UAS activities at Gatwick Airport[5] in 2018 to the drone attack at Air Force Station, Jammu[6] in 2021 are just a few examples from many. By adopting UTM systems, the defence forces can establish secure communication networks, implement geofencing and no-fly zones, and enforce airspace restrictions for unauthorized or malicious UAS activities. The US Customs and Border Protection agency is in the process of employing UTM systems to enhance border surveillance along the US-Mexico border[7]. The Indian Military on similar lines can leverage UTM technologies to optimize patrol routes, deploy resources effectively in HADR missions and enhance response capabilities in case of border incidents.

(c) *International collaboration and Indigenous industry growth*: By being at the forefront of UTM implementation, with International and domestic collaborations the Indian Armed Forces can foster the growth of domestic industry in the development of UTM platforms, communication networks, geospatial information systems, and airspace management solutions. This involvement not only fosters the growth of the indigenous aerospace industry but also boosts collaboration with startups and SMEs in the aerospace sector, thereby promoting self-reliance and reducing dependence on foreign suppliers boosting the "Make in India" initiative by the Government of India.

(d) *Operational Expertise*: The IAF's expertise in aviation operations, surveillance, and security can significantly contribute to the development and implementation of robust UTM systems. With theater commands established, the theatre commander who would have the authority and responsibility for all assets, including ground forces and aerial assets (manned and unmanned} as well as a composite battlefield picture will be able to ensure that drone strikes are conducted safely, avoiding potential airspace conflicts and minimizing the risk to friendly forces and civilians.

(e) The IAF in collaboration with regulatory authorities, should establish a robust policy and regulatory framework for UTM implementation. This framework should address safety, security, privacy, and interoperability concerns while encouraging innovation and growth in the UTM ecosystem.

Technological Infrastructure

Various technologies that can contribute to the safe and efficient integration of UAS into the Indian airspace:

(a) *ATM Automation Systems*: These systems utilize pre-programmed algorithms along with data processing capabilities and decision-making tools to optimise airspace utilisation by regulating air traffic and enhancing situational awareness for UTM operators and air traffic controllers. The integration of UAS-specific automation capabilities into existing ATM systems

can enable seamless coordination between manned and unmanned aircraft operations.

(b) *Remote Identification and Tracking Technologies*: These are essential for identifying and tracking UAS operating in the airspace. RID systems enable UTM stakeholders, including regulators, airspace authorities, and law enforcement agencies, to remotely identify and authenticate UAS. These technologies can employ Unique Identification Numbers (employed in Indian DigitalSky[8] portal), radio frequency (**"RF"**) systems, or other electronic means to ensure the traceability and accountability of UAS. Advanced tracking technologies, such as radar, Automatic Dependent Surveillance-Broadcast ("**ADS-B"**), and multilateration, provide real-time tracking of UAS, enhancing overall airspace awareness and safety. RIT as per the National UTM policy framework is emphasised in detail subsequently.

(c) *UTM Platforms and Software*: UTM software solutions incorporate advanced algorithms, data analytics, and visualization tools to optimize UAS traffic flow, ensure separation between aircraft, and monitor compliance with airspace regulations. DigitalSky[9] Platform by the Ministry of Civil Aviation along with startups like SKYEAIR[10.] is a good step in this direction.

(d) *Communication and Data Exchange Protocols*: Efficient and reliable communication systems and data exchange protocols are vital for UTM operations. UTM stakeholders need seamless and secure communication channels to exchange critical information, such as flight plans, weather updates, and situational awareness data. Integration of modern communication technologies, including cellular networks, satellite communication systems, and dedicated UAS communication networks, can enhance the reliability and coverage of UTM communications. However the primary emphasis of research should be to reduce the latency of communication.

(e) *Sense and Avoid Systems*[11]: These systems are designed to prevent collisions between UAS and other aircraft or obstacles in the airspace. These systems employ various sensors, including radar, lidar, cameras, and on-board avionics, to detect and track surrounding aircraft and hazards. By utilizing advanced algorithms and real-time data processing, sense and avoid systems can provide UAS operators with situational awareness and enable automated collision avoidance manoeuvres. With FSD (Full Self Drive) capabilities in cars, these systems are very much a possibility in the near future.

(f) *Geofencing*[12] *Technologies*: Geofencing technologies define virtual boundaries in the airspace, allowing UTM operators to establish no-fly zones, restricted areas, and geographically specific flight restrictions. Geofencing systems utilize GPS or other positioning technologies to enforce predefined boundaries and provide UAS operators with real-time information regarding airspace restrictions and hazards. These technologies help prevent

unauthorized or unsafe UAS operations in sensitive areas, such as airports, critical infrastructure,military zones and populated regions.

(g) *Artificial Intelligence (AI) and Machine Learning (ML)[13] Applications*: AI and ML technologies have immense potential in enhancing UTM operations. AI algorithms can analyse vast amounts of data collected from UAS, air traffic, weather, and other sources to provide predictive analytics, anomaly detection, and decision support. ML models can learn from historical data to improve flight planning, optimize traffic flow, and identify patterns that contribute to enhanced safety and efficiency in UTM operations.

(h) *Integration with Existing Air Traffic Management Infrastructure[14]*: Integrating UTM with the existing air traffic management infrastructure is crucial for seamless coordination between manned and unmanned aircraft operations. UTM systems should be interoperable with the traditional ATM systems to exchange critical information, ensure situational awareness, and enable efficient airspace management. Integration can be achieved through standardized interfaces, data exchange protocols, and collaborative decision-making platforms.

(i) *Emerging Technologies and Research Areas*: UTM implementation in India should embrace emerging technologies to address future challenges and opportunities. These may include the use of blockchain[15] technology for secure data sharing and authentication, advanced UAS navigation systems, energy-efficient UAS platforms, swarm technology[16], cybersecurity solutions for UTM, and advanced human-machine interfaces for UAS operators and air traffic controllers.

Integrating these technologies, will play a pivotal role in the successful implementation of UTM in India. However, further research and development along with collaboration between the Indian Armed Forces, industry players, startups, SMEs, academia, and research institutions is vital for driving innovation and pushing the boundaries of UTM implementation.

Policy Progress and Challenges in UTM Implementation in India:

India has been making technological progress in UTM implementation focusing on UTM architecture and its relevant technologies. However, challenges in terms of policy framework need to be addressed to ensure the successful and widespread adoption of UTM in India.

(a) *Policy Framework*: India has made progress in developing a policy framework to govern UTM operations. The Directorate General of Civil Aviation ("**DGCA"**) has been working on regulations and guidelines to ensure safe UAS operations and UTM integration[17]. This includes the classification of airspace for UAS operations, licensing and certification requirements, and operational procedures for UTM service providers.

(b) *Regulatory Challenges*: These challenges include the classification of airspace and establishing clear regulations for UAS operations, especially low altitude operations[18]. The integration of UTM into existing air traffic management frameworks, while ensuring safety and efficiency, requires careful coordination and collaboration among regulatory authorities, airspace managers, and UTM stakeholders.

(c) *Infrastructure Challenges*: India faces infrastructure challenges in terms of limited communication networks and UAS surveillance systems. The availability and reliability of communication infrastructure, including cellular networks and data connectivity in remote areas, pose challenges for real-time data exchange in UTM operations[19]. Additionally, the deployment of UAS surveillance systems, such as radar or ADS-B, requires adequate infrastructure to ensure comprehensive airspace coverage.

(d) *Public Acceptance and Privacy Concerns*: Ensuring public acceptance of UAS operations and addressing privacy concerns is a significant challenge in UTM implementation[20]. Public awareness campaigns, education programs, and stakeholder consultations are necessary to address misconceptions, build trust, and mitigate privacy-related apprehensions associated with UAS operations and UTM systems.

(e) *Industry Collaboration and Standardization*: Promoting collaboration among industry players and establishing standardized practices and protocols are crucial for UTM implementation. Encouraging industry partnerships, research collaborations and information-sharing platforms can accelerate technological advancements and promote interoperability among UTM systems and stakeholders.

A Summary of Progress In UTM Across The World

A detailed study of the roadmap/ progress of UTM implementation in different countries and by major companies would be a reverse-engineered approach in brainstorming and implementation of UTM in the Indian context.

(a) The United States has made significant progress in UTM implementation, driven by collaborations between government agencies, industry stakeholders, and research institutions. The Federal Aviation Administration (**"FAA**") has been at the forefront of UTM regulations and development of key technologies. One such notable initiative is the UAS Integration Pilot Program ("**IPP"**)[21] aimed to accelerate UAS integration by collaborating with state as well as private sector partners facilitating various UTM projects and trials.

(b) Companies such as Amazon, Wing (a subsidiary of Alphabet Inc.), Boeing and GE have been actively involved in UTM research and development, particularly in the context of delivery drone operations. They

have been working on technologies like sense and avoid systems, autonomous navigation, and UTM software platforms.[22]

(c) NASA[23] has developed a comprehensive UTM architecture that enables the safe and efficient integration of UAS into the national airspace. It utilizes algorithms and decision support tools to optimize traffic flow, deconflict routes, and ensure safe operations. NASA has been working on standardized communication protocols, such as the UAS Traffic Management Communication System (**"UCS"**), to enable seamless information exchange between UAS operators, air traffic controllers, and UTM service providers.

(d) Europe has also been actively pursuing UTM implementation, with a focus on harmonizing regulations and developing UTM technologies. The European Union (EU) has launched the U-space program to establish a framework for the safe and efficient integration of UAS including geofencing, detect and avoid systems, and electronic identification. Single European Sky ATM Research[24] (**"SESAR")** is a collaborative program aimed at modernizing Europe's air traffic management system. focusing on technologies like UAS surveillance, communication systems, and UTM architecture. Companies like DJI, a leading drone manufacturer, have been involved in UTM-related research and development, including technologies such as remote identification, geofencing, and flight planning applications.

(e) Switzerland has been a pioneer in UTM implementation through its Swiss U-space initiative. Similarly, Japan has been conducting trials and research on UTM technologies, with a focus on autonomous UAS operations, UAS traffic management, and UTM regulations. Companies like Intel, Qualcomm, and Airbus are actively involved in UTM research and development, working on technologies such as advanced collision avoidance systems, real-time UTM data processing, and UAS network connectivity[25].

Collaborative efforts between government agencies, industry stakeholders, and research institutions have been driving safe integration of UAS into the airspace and industry-academia-armed forces collaboration should be the way forward for India too.

Real-Time Identification and Tracking ("RIT")

RIT refers to the functionality of unmanned aircraft systems (UAS) to transmit their identity, location, and other relevant information to a UTM Service Provider (**"UTMSP"**) or other stakeholders in real-time. RIT or Remote ID of unmanned aircraft is a critical requirement for enabling high-density and complex unmanned aircraft operations. There are two main methods of RIT as per the policy framework[26] : RIT via Broadcast and RIT via Network.

(a) *RIT via Broadcast*: This functionality allows an unmanned aircraft to advertise its identity, location, and other information over WiFi and/or Bluetooth. The information can be received and displayed by hand-held devices such as mobile phones. Manufacturers would need to integrate

additional hardware to enable this functionality. However, the operational range of RIT via Broadcast is limited to less than 100 meters due to conventional WiFi and Bluetooth standards, making it impractical for identifying unmanned aircraft in most scenarios.

(b) *RIT via Network*: This functionality involves the transmission of unmanned aircraft information, including identity, location, and other data, to a UTM Service Provider (UTMSP) using internet and other communication networks. It allows UTMSPs to centrally monitor the position of all unmanned aircraft, share information with other UTMSPs, and manage traffic by providing advisories if necessary. RIT via Network overcomes the range limitations of RIT via Broadcast. However, it is important to note that this functionality may not be available in areas without a telecommunication network.

As per the current defined policy, The RIT message should at least contain:

(a) Unique Identification Number (UIN) of the unmanned aircraft

(b) Location of the UAS including its latitude, longitude and barometric pressure altitude

(c) Timestamp (in UTC)

(d) Intent information (heading and ground speed)

(e) Emergency status of the UAS such as Command and control link loss.

The policy framework released in 2021, has still not mandated the use of Remote ID for UAS in India. However, the Indian Air Force can and should leverage Remote ID in the implementation of UTM. Outlined below is a guideline for Remote ID utilisation by the Indian Air Force in UTM implementation:

(a) *Ensuring Compliance and Security*: Remote ID enables the Indian Air Force to verify the identity of UAS operating within the airspace. By mandating Remote ID for all UAS, the Indian Air Force can ensure that only authorized and compliant UAS are operating, thereby enhancing airspace security and preventing unauthorized or malicious activities. Recently, the Ministry of Civil Aviation has granted permits to "No-Permission-No-Takeoff" (“**NPNT”**)[27] compliant drone operations at 166 additional green zones[28] to facilitate and promote UAV operations in the country. NPNT is a software program that enables every Remotely Piloted Aircraft (except Nano drones) to obtain a valid permission (UIN) through the DigitalSky platform before operating in India. If an NPNT compliant drone tries to breach geo-fencing i.e. try and go beyond the permissible boundary in the airspace, the built-in software will compel the drone to abort the mission and return-to-home (**“RTH”**)

(b) *Real-time Monitoring and Tracking*: Remote ID provides real-time information about the location, altitude, and flight trajectory of UAS. This information can be accessed by the Indian Air Force and other relevant stakeholders to monitor UAS activities, identify potential airspace conflicts and take appropriate actions if necessary. Real-time tracking enhances situational awareness, enabling timely decision-making and effective airspace management[29].

(c) *Integration with Air Traffic Control*: Remote ID data can be integrated with existing air traffic control systems (e.g. IACCS) to provide comprehensive airspace situational awareness. By sharing Remote ID information with air traffic controllers, the Indian Air Force can ensure the safe integration of UAS into manned aircraft operations, facilitating efficient and seamless air traffic management.

(d) *Response to Unauthorized UAS*: In cases where unauthorized or suspicious UAS are detected, Remote ID can provide valuable information for rapid response and interception. The armed forces can leverage Remote ID data to identify the operator or owner of the UAS, enabling appropriate enforcement actions to be taken to mitigate potential threats or violations of airspace regulations[30].

(e) *Collaboration with Law Enforcement Agencies*: Remote ID data can be shared with law enforcement agencies, enabling them to monitor UAS activities, investigate any potential security breaches, and take necessary actions. This collaboration enhances the overall security framework and ensures a coordinated approach to UAS operations within the airspace.

Counter-UAS technology- DIAD Model

While counter-UAS technologies continue to make inroads with respect to the detection of vehicles in cluttered environments (for example, an urban setting), rapid UAS identification and the ability to distinguish participating from non-participating actors in the UTM system remains a significant challenge. Example: ANRA SIAOP – which stands for “Single Integrated Airspace Operational Picture” – combines aspects of both technologies to offer a single, complete view of the airspace designed to help both operators and authorities[31].

For comprehensive, end-to-end counter-UAS solutions, the **DIAD (“Detect Identify Assess Defeat”)** model inspired from the famous OODA loop by Col John Boyd[32] provides a systematic approach for countering UAS threats.

Detect: The first step is to detect an unauthorised UAS within the airspace. This can be achieved through various sensor systems including radar, EO cameras, acoustic sensors and radio frequency (RF) detection systems. The UAS position, velocity and track estimate with a UIN will help distinguish authorised from unauthorised UAS.

Identify: The next step is to identify the UAS attributes. Remote ID systems enable the identification and tracking of UAS by transmitting UIN, such as the drone's serial number, flight path, and operator details.

Assess: After the UAS is detected and identified, an assessment of UAS behaviour, flight trajectory and any potential risks (low/ medium/ high) it may pose to critical infrastructure, public safety or national security is carried out. Artificial intelligence along with advanced algorithms can provide real-time and actionable intelligence to the authorities.

Disrupt: If the UAS risk metric declares the UAS unauthorized or malicious, appropriate countermeasures could be deployed to disrupt its operations. This can include KE measures such as signal jamming, GPS spoofing, or the use of directed energy systems or counter drones so as to disable or divert the UAS. This should be done while minimizing collateral damage and ensuring the safety of other airspace users.

The endeavour should be to utilise the DIAD model to build up counter UAS solutions integrated with Remote ID and low latency communication protocols.

Training And Skill Development

Effective UTM implementation would require a skilled workforce equipped with the necessary knowledge and expertise to manage and operate UTM systems.The armed forces will have to develop specialized training programs to equip personnel with the necessary skills and knowledge for UTM operations.

(a) *UAS Operations*: Understanding UAS operations, flight dynamics, mission planning, and payload integration.

(b) *Airspace Managemen*t: Knowledge of airspace regulations, traffic management, and coordination with air traffic control.

(c) *Communication and Data Exchang*e: Proficiency in UTM communication protocols, data exchange systems, and network security.

(d) *Situational Awareness*: Ability to interpret and analyse UTM data, airspace traffic, and potential conflicts for effective decision-making.

(e) *Emergency Response*: SOPs for emergency response, incident/ accident management and contingency planning.

Conclusion

In conclusion, the IAF and now the air wing of the theatre command must play a proactive role in implementation of UTM systems in order to ensure seamless integration of unmanned and manned aircraft systems within the same airspace.

The adoption of Remote ID emerges as a paramount consideration for the secure integration of UAS into the national airspace. Through the mandated implementation of Remote ID, the Indian Military can elevate airspace security and facilitate the seamless integration of UAS operations. The armed forces must establish robust

technological infrastructure while concurrently formulating and reiterating a comprehensive policy framework. Drawing from the experiences of other nations and reverse engineering their successful UTM implementations can serve as a viable roadmap. By studying their methodologies and assimilating insights, the IAF can navigate potential pitfalls and expedite the implementation process. By adhering to the steps of Detect, Identify, Assess, and Disrupt, the armed forces can effectively address unauthorized and potentially malicious drone activities, thereby fortifying airspace security. With regard to personnel, the armed forces must prioritize a workforce equipped with the necessary knowledge and skills for UTM sustenance and management.

Overall, through active engagement in UTM implementation, the Indian Armed Forces can contribute significantly to national security, augment operational capabilities, and assume a leadership position in the adoption of advanced aerospace technologies.

Recommendations

Based on the analysis presented in this paper, the following recommendations are proposed:

(a) Formulate a comprehensive policy framework that addresses UTM regulations, VLL airspace management, defines roles and responsibilities of various stakeholders viz. UTM service providers, technology companies, and drone operators. The framework should solve the Remote ID requirement problem as well as provide space for counter-UAS technology implementation in the same framework.

(b) Foster partnerships with industry stakeholders, incentivise the academia and research institutions to leverage their expertise and resources in UTM implementation in India. This collaboration can expedite the process and facilitate knowledge sharing.

(c) A specialized team or a dedicated division within the theatre command that focuses on UTM implementation and its management could be established. This division should be responsible for developing strategies, based on ISR data while ensuring compliance with the evolving UTM regulations.

(d) Acquire and deploy advanced UTM technologies along with geofencing of defence/ sensitive areas in addition to counter-UAS capabilities.

(e) Develop training programs to ensure the proficiency of armed forces personnel in handling UTM operations. This includes training on UTM systems operations and management, along with counter-UAS procedures. Trained manpower following a feedback loop will ensure timely upgrades in the technology.

(f) UTM implementations in other countries such as the USA, EU and Japan should be studied in depth. By collaborating with other nations, the

armed forces can stay updated on global UTM advancements, share experiences, and contribute to the development of international UTM standards.

(g) Initiate pilot projects to test and evaluate existing UTM technologies and procedures in real-world scenarios. These can help identify operational challenges, refine the UTM systems and gather data for future implementations.

(h) Theater command framework would ensure better integration and employment of all military UAV assets to strategically support mission objectives.

By embracing UTM, the IAF aligns with the Air Force Doctrine and National Security Objectives, thereby guaranteeing the secure and seamless integration of UAS operations while upholding airspace security.

DISCLAIMER

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