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Abstract

Drones, also known as unmanned aerial/ underwater vehicles (UAV/ UUV), are innovative and transformative machines that navigate the skies and the seas, equipped with advanced technologies, sensors, and capabilities that enable them to perform a wide range of tasks with precision, efficiency, and adaptability. The advent of micro-electronics, advanced sensors, and miniaturisation in the latter half of the 20th century has propelled the development of modern drone technology with the United States played a pioneering role in this regard. Drones can be classified based on various factors, including size, capabilities, and application. The Directorate General of Civil Aviation (DGCA) governs the operation of drones through the Civil Aviation Requirements (CAR) and the Drone Rules, 2021. The Indian Navy has recognised the significant potential of drones and unmanned aerial vehicles and has been actively incorporating them into its operations. Unmanned aerial systems provide the Indian Navy with enhanced situational awareness, extended reach, and improved operational capabilities whereas the Unmanned Underwater Vehicles help develop the Underwater Domain Awareness including combat capabilities. It is high time that India identifies the potential of the future possibilities and substantial efforts need to be undertaken to bring together all stakeholders (the Armed Forces, DGCA, the Ministry of Home Affairs, the Private Industry, DRDO and DPSUs) to achieve a common goal. There lies no argument over the fact that Drones/ UAVs/ UUVs/ AUVs will redefine traditional approaches to military strategy in the coming future.

सुमेरुश्चैव मार्गश्च द्यूतश्चैव निवेशनः। अपराजितश्चैवेन्द्रः पुष्पकः पर्वतोपमः॥
(Ramayana, Uttara Kanda 101.18)

Transliteration: *Sumeruścaiva mārgaśca dyūtaścaiva niveśanaḥ*
Aparājitaścaivaindraḥ puṣpakaḥ parvatopamaḥ

Translation: The Pushpak Vimana is incomparable, like Mount Sumeru, with well-constructed pathways, splendid abodes, Indestructible and victorious, belonging to Indra.

(This verse highlights the grandeur and uniqueness of the Pushpak Vimana, comparing it to Mount Sumeru, the mythical mountain known for its immense size and significance in Hindu mythology. The Pushpak Vimana is described as having well-structured pathways, luxurious accommodations, and being indestructible, symbolising its extraordinary nature).

History and Introduction of Drones

Drones, also known as unmanned aerial vehicles (UAVs), are autonomous or remotely piloted aircraft that have transcended conventional boundaries of human-controlled flight. They are innovative and transformative machines that navigate the skies, equipped with advanced technologies, sensors, and capabilities that enable them to perform a wide range of tasks with precision, efficiency, and adaptability. Drones embody the fusion of aerial mobility, cutting-edge automation, and intelligent systems, serving as versatile tools that extend human reach, expand operational possibilities, and provide unprecedented perspectives on our world.

The history and advent of drones have brought about a transformative shift in various sectors worldwide. Originally developed for military purposes, drones have evolved into versatile unmanned aerial vehicles (UAVs) that find applications in industries such as photography, delivery services, agriculture, surveillance, and more. In the next few paragraphs, I will bring out an overview of the history and development of drones, highlighting key milestones and their impact on society.

Early Beginnings of Drones. The concept of unmanned aerial vehicles can be traced back to the early 20th century. In 1916, during World War I, the Hewitt-Sperry Automatic Airplane[1], also known as the "*Aerial Torpedo*," was developed by Elmer Sperry and Peter Hewitt of the United States of America. This remote-controlled aircraft was intended to serve as a bomb-carrying platform. Subsequently, various nations explored the potential military applications of drones. Interestingly, it was the US Navy

that initially recognised the potential of this technology for implementation in the maritime domain.

Military Applications and Advancements. Drones gained significant traction during World War II when both the Allies and Axis powers experimented with remotely piloted aircraft. The British Royal Navy's "*Queen Bee*[2]" was among the earliest successful target drones used for training anti-aircraft gunners. The development of jet-powered drones, such as the American "*Firebee*," further expanded their military applications. The American "*Firebee"* drone was first introduced in the 1951 and was a pioneering unmanned aerial vehicle and played a pivotal role in advancing military reconnaissance capabilities. Its development marked a significant milestone in the evolution of drone technology.

Rise of Modern Drone Technology. The advent of micro-electronics, advanced sensors, and miniaturisation in the latter half of the 20th century propelled the development of modern drone technology. The United States played a pioneering role in this regard, with projects like the "*Predator*[3]" and "*Global Hawk*[4]" drones, which showcased the capabilities of unmanned aerial systems for surveillance, reconnaissance, and combat operations post the 1990s.

Civilian and Commercial Applications. In recent decades, drones have transitioned from predominantly military use to civilian and commercial applications also. The emergence of lightweight materials, improved battery technology, and affordable consumer-grade drones fuelled their popularity among hobbyists, photographers, and videographers. Aerial photography, film production, and recreational drone racing are some examples of civilian applications that gained prominence.

Types of Drones In Today's Era

Drones can be classified based on various factors, including size, capabilities, and application.

Size-based Classification

- **Nano Drones**. Smallest and highly portable, used for indoor flights, close-range inspections, and recreation (less than 250 grams).

- **Micro Drones**. Slightly larger, with increased stability and payload capacity for aerial photography and recreation (more than 250 grams but less than 2 kilograms).

- **Small Drones**. Versatile with longer flight times, used in agriculture, surveying, and aerial inspections (2 kilograms to 25 kilograms).

- **Medium Drones**. Robust, with increased payload capacity for professional applications like mapping and inspections (25 kilograms and 150 kilograms).

- **Large Drones**. Heaviest and most powerful, used in military operations and heavy-lift cargo transportation (exceed 150 kilograms).

Application-based Classification

- **Military Drones**. Equipped with advanced sensors and weapons for reconnaissance, surveillance, and combat.

- **Photography and Videography Drones**. High-resolution cameras for aerial photos and videos in film, real estate, events, and aerial footage.

- **Surveying and Mapping Drones**. Specialised sensors like LiDAR for precise data collection, used in urban planning and environmental monitoring.

- **Agriculture and Farming Drones**. Crop monitoring, targeted application of fertilizers and pesticides for improved farming practices.

- **Delivery Drones**. Short-distance transport for last-mile delivery, medical supplies, and disaster response.

- **Inspection and Maintenance Drones**. Visual inspection of infrastructure, ensuring safer maintenance operations.

- **Search and Rescue Drones**. Thermal cameras aid in search and rescue operations, providing real-time data.

- **Recreational and Racing Drones**. Aerial acrobatics and racing competitions for leisure and competitive flying.

- **Security and Surveillance Drones**. Aerial surveillance for critical infrastructure, border control, and public safety.

- **Environmental Monitoring Drones**. Wildlife tracking, forest surveying, pollution monitoring, coastal research.

- **Industrial and Construction Drones**. Site inspections, project monitoring in mining, oil and gas, and construction industries.

Capabilities-based Classification

- **Fixed-Wing Drones**. Resemble airplanes, designed for long-endurance flights, used for mapping and surveillance.

- **Multirotor Drones**. Have multiple rotor blades, can hover, take off vertically, used for aerial photography and inspection.

- **Single-Rotor Helicopters**. Feature a large main rotor and smaller tail rotor, offer more lift capacity, used for professional aerial photography and videography.

- **Hybrid VTOL Drones**. Combine fixed-wing and multirotor capabilities, suitable for tasks requiring vertical take-off and longer-range flights.

- **Tethered Drones**. Connected to the ground by a cable, provide continuous power and stable operations, used for persistent surveillance and communication relay.

- **Stealth Drones**. Military drones designed for reconnaissance, precision strikes, and intelligence gathering while minimising radar signature.

It's important to note that these classifications are not exhaustive, and the categorisation of drones may vary based on different criteria used by organisations and regulatory bodies.

Drone Regulations in India: A Comprehensive Overview

The advent of drones has presented new opportunities and challenges for governments worldwide. In India, the rapid proliferation of drones has led to the establishment of regulations to ensure their safe and responsible use. In the next few paragraphs, I provide a comprehensive overview of the drone regulations in India, including registration requirements, operational guidelines, and the regulatory framework governing their usage.

Regulatory Framework. The Directorate General of Civil Aviation (DGCA), the regulatory body for civil aviation in India, governs the operation of drones through the Civil Aviation Requirements (CAR) and the Drone Rules, 2021[5]. These rules aim to strike a balance between promoting drone operations and ensuring safety and security of airspace and the public.

Drone Categories and Classification. Under the Drone Rules 2021, drones in India are categorised based on their Maximum Take Off Weight (MTOW) as follows.

- **Nano Drones**. MTOW less than or equal to 250 grams.

- **Micro Drones**. MTOW greater than 250 grams and less than or equal to 2 kilograms.

- **Small Drones**. MTOW greater than 2 kilograms and less than or equal to 25 kilograms.

- **Medium Drones**. MTOW greater than 25 kilograms and less than or equal to 150 kilograms.

- **Large Drones**. MTOW greater than 150 kilograms.

Drone Registration and Operator Requirements. All drone operators in India are required to register their drones and obtain a Unique Identification Number (UIN) or Drone Acknowledgment Number (DAN) from the Digital Sky Platform, an online portal established by the DGCA. The registration process involves providing necessary details, including the purpose of operation, intended area of operation, and drone specifications.

Drone Pilot Requirements. Drone pilots operating drones in the micro, small, medium, and large categories are required to obtain a remote pilot license (RPL) from the DGCA. The RPL is obtained by completing the prescribed training, passing the relevant examinations, and fulfilling other eligibility criteria set by the DGCA.

No-Fly Zones and Restricted Areas. To ensure safety and security, certain areas are designated as "No-Fly Zones" or "Restricted Areas" where drone operations are prohibited or strictly regulated. These include airports, military installations, government buildings, and other sensitive locations. Drone operators must adhere to these restrictions and obtain necessary permissions for operations in restricted areas.

Operational Guidelines. The Drone Rules 2021, define various operational guidelines for drone flights in India, including:

- **Visual Line of Sight (VLOS)**. Drones must be operated within visual line of sight of the remote pilot at all times, ensuring direct visual contact with the drone.

- **Height Restrictions**. Drones must not fly above a maximum height of 400 feet (120 meters) above ground level, unless specifically permitted.

- **Time of Operation**. Drone flights are permitted only during daylight hours, from sunrise to sunset, unless approved by the DGCA.

- **Safety Considerations**. Drone operators must prioritise the safety of people, property, and other aircraft during operations. They must avoid endangering life, causing damage, or interfering with manned aviation.

- **Beyond Visual Line of Sight (BVLOS) Operations and Experimental Drone Flights**.The Drone Rules 2021, allow for the conduct of BVLOS operations and experimental flights under specific circumstances. However, prior approval from the DGCA is mandatory for such operations, and additional safety measures and protocols must be followed.

Usage of Drones in the Maritime Domain

Aerial Drones (UAVs). The Indian Navy has recognised the significant potential of drones and unmanned aerial vehicles and has been actively incorporating them into its operations. These unmanned aerial systems provide the Indian Navy with enhanced situational awareness, extended reach, and improved operational capabilities. Drones enable the Navy to monitor and secure India's maritime borders, detect and track potential threats, gather intelligence, undertake search and rescue, and support missions with reduced risks to human personnel. Their utilisation strengthens the Navy's capabilities in safeguarding coastal areas and contributing to overall maritime security efforts. Some of the key applications of UAVs in maritime domain are discussed below.

- **Maritime Surveillance**. Drones can monitor and secure maritime territories, coastal areas, and economic zones, providing real-time situational awareness and supporting intelligence gathering.

- **Search and Rescue Operations**. Drones can assist in sea-based search and rescue operations, covering large areas quickly, locating survivors or distressed vessels, and aiding rescue efforts.

- **Coastal Surveillance**. Drones can monitor and protect coastal areas from smuggling, piracy, and intrusions, providing real-time video feeds and detecting suspicious activities.

- **Aerial Combat Support**. Unmanned combat aerial vehicles (UCAVs) equipped with precision munitions can support naval aerial combat with reconnaissance, surveillance, and strike capabilities.

- **Force Multiplier**. Drones can act as force multipliers by operating in swarms, covering larger areas, and enhancing the effectiveness of naval operations.

- **Logistic Support and Resupply**. Drones provide logistic support and resupply capabilities to naval forces, transporting supplies and aid, and offering rapid response in emergencies.

Unmanned Underwater Vehicles (UUVs). In the late 1880s, the Spanish and British empires commanded global dominance through their formidable Armadas, while the Nazis became known for their renowned U-Boats and the United States for their mighty aircraft carriers. The emergence of Unmanned Underwater Vehicles (UUVs) marks a new era in naval power. These autonomous or remotely operated underwater vehicles are designed to operate in challenging environments without direct human intervention. Equipped with sensors, cameras, and navigation systems, UUVs gather data, capture images, and perform specific missions. They find applications in marine exploration, surveillance, research, and various industries. UUVs enhance underwater operations, mitigate risks to human divers, and contribute to achieving Underwater Domain Awareness (UDA). These valuable assets play a significant role in modern military

strategies and operations, unlocking the potential of the ocean depths for exploration and research.

Swarming UUVs. An emerging area of focus lies in the development of UUV swarms. These swarms consist of numerous small, lightweight drones interconnected like a network, resembling the collaborative behaviour of bees and controlled with Artificial Intelligence based algorithms. They possess a cost-effective method to inflict significant harm on expensive enemy submarines and aircraft carriers, thus altering the dynamics of naval warfare.

Type of UUVs. The Indian Navy has categorised UUVs into four types[6]: -

- Man-Portable Autonomous Unmanned Vehicles (AUVs) with swarm functionality with an endurance of the order of 10 to 20 hours.

- Lightweight AUVs compatible with the existing lightweight torpedo tubes onboard ships and endurance of about two days.

- Heavyweight AUVs compatible with the existing heavyweight tubes and endurance of the order of 3 to 4 days.

- High endurance AUVs with a capability of at least 15 days submerged endurance.

Applications of UUVs. Some of the key application of UUVs in maritime domain are discussed below.

- **Mine Countermeasures (MCM)**. UUVs and ROVs can locate and neutralie underwater mines, ensuring safer navigation without risking human lives.

- **Anti-Submarine Warfare (ASW)**. UUVs can enhance ASW capabilities by detecting and tracking enemy submarines, providing valuable information and reducing risks to human operators.

- **Intelligence, Surveillance, and Reconnaissance (ISR)**. UUVs equipped with sensors and cameras can contribute to covert missions, collecting data on underwater assets and enhancing situational awareness.

- **Underwater Mapping and Surveying**. UUVs can map and survey underwater terrains, providing detailed charts for navigation and operational planning.

- **Salvage and Recovery Operations**. UUVs can locate and recover sunken vessels or debris, equipped with tools for underwater tasks.

- **Environmental Monitoring**. UUVs can assess marine environments, monitoring water quality, biodiversity, and ecosystem health for environmental studies and resource management.

India's UUV Capabilities. India's progress in the development of Unmanned Underwater Vehicles (UUVs) is still in its early stages and necessitates a comprehensive and collaborative approach involving all stakeholders. Recently, Larsen & Toubro (L&T) entered into a memorandum of understanding with Bengaluru-based New Space Research & Technology[7] to develop UUVs primarily for surveillance purposes. At the recent Defence Expo, L&T showcased its Adamya, Amogh, and Maya Autonomous Underwater Vehicle (AUVs). The Adamya AUV is designed to be launched from a submarine's 533 mm torpedo tubes and has an operational endurance of over eight hours. In June 22, the Ministry of Defence has commenced the initial process of acquiring AUVs or underwater drones with dual capabilities for observation and strike purposes. Additionally, the Defence Research and Development Organisation (DRDO) has developed flat-fish-shaped UUVs, which are equipped with pre-programmed algorithms and mission-specific requirements.

Chinese advancements in UUVs. China's UUV programs, including their underwater gliders and remotely operated vehicles (ROVs), have been observed operating in the IOR and it has drawn attention from regional and global stakeholders, impacting the dynamics of maritime security and strategic interests in the region. These UUVs are employed for various purposes, including marine research, oceanographic surveys, and potentially for gathering intelligence. One notable example is China's Haiyi (Sea Wing) family of UUVs, which includes both large and small-scale vehicles. These UUVs are capable of conducting tasks such as underwater mapping, surveillance, intelligence gathering, and even mine countermeasures.

China has also developed other types of UUVs, including remotely operated vehicles (ROVs) and autonomous underwater gliders, which are used for different purposes such as deep-sea exploration, marine scientific research, and underwater inspections. Furthermore, China's progress in UUV technology has been supported by their advancements in artificial intelligence, sensors, and communication systems.

US Navy advancements in UUVs. The US Navy has awarded a contract to Boeing for the development of the Orca XLUUV (Extra-Large Unmanned Undersea Vehicle). The Orca is designed for long-range autonomous missions and can perform a range of tasks, including surveillance, mine countermeasures, and anti-submarine warfare. The Snakehead UUV is a modular, open-architecture UUV which is designed to support a range of missions, including intelligence gathering, reconnaissance, and mine warfare. The Knifefish UUV is another project aimed at mine-hunting system and was developed for the U.S. Navy's Littoral Combat Ship. It uses advanced sonar technology to detect and classify underwater mines, providing a safer alternative to manned mine-hunting operations. In the recent past, the US Navy has also been conducting tests and demonstrations of the Ghost Fleet Overlord UUVs and the Bluefin-21 UUVs which have all displayed immense potential in maritime applications.

Defence against Adversary Drones

Defending against drones, particularly those with malicious intent, has become a critical concern in modern warfare and security. Several methods and technologies can be employed to counter the threats posed by hostile drones. An effective counter-drone strategy often involves a combination of multiple defence measures to mitigate the risks associated with drones and some of the common defence measures are discussed below.

- **Radio Frequency (RF) Jamming**. RF jamming disrupts the communication link between the drone and its operator by emitting radio signals that interfere with the drone's control systems. This can force the drone to either land or return to its operator.

- **Drone Detection Systems**. Drone detection systems use various technologies such as radar, acoustic sensors, and radio frequency (RF) scanners to detect and track drones within a specific area. These systems provide early warning and situational awareness to security personnel.

- **Drone Capture and Interception**. Anti-drone systems can physically capture or intercept drones to neutralise the threat. This can be done using net guns, trained birds of prey, or other mechanisms to physically disable or immobilise the drone.

- **Laser Systems**. Laser-based systems can be used to disable or disrupt the functionality of drones. High-powered lasers can target the drone's sensors or control systems, causing damage or forcing the drone to abort its mission.

- **Anti-Drone Drones**. Specially designed drones equipped with nets, projectiles, or other countermeasures can be deployed to intercept and neutralise unauthorised or malicious drones. These counter-drone drones can disable the target drone or force it to land safely.

- **Kinetic Countermeasures**. Using firearms, specialised anti-drone guns, or directed energy weapons to physically disable or shoot down enemy drones. These countermeasures can include projectiles or nets designed to intercept and neutralise the drone threat.

- **Drone Shielding and Protected Areas**. Establishing protected areas or deploying physical barriers, such as drone shields or anti-drone nets, can prevent unauthorised drones from entering sensitive locations and airspace.

- **Legislation and Regulation**. Implementing strict regulations and laws governing the use of drones can help deter unauthorised or malicious activities. This includes enforcing no-fly zones, registration requirements, and penalties for violating drone regulations.

Future Prospects and Challenges

The United States has long been at the forefront of drone technology advancements, while China has also made significant strides in the field over the past two decades. It is high time that India identifies the potential of the future possibilities and substantial efforts need to be undertaken to bring together all stakeholders (the Armed Forces, DGCA, the Ministry of Home Affairs, the Private Industry, DRDO and DPSUs) to achieve a common goal. There lies no argument over the fact that Drones/ UAVs/ UUVs/ AUVs will redefine traditional approaches to military strategy in the coming future.

However, challenges such as airspace regulations, safety concerns, privacy issues, and public acceptance remain critical areas of focus for the widespread integration of drones into society.

Quoting from the preface written by John Bruno Hare in the book "*Maharishi Bharadvaja's Vymaanika Shaashtra (or Science of Aeronautics)*" translated by GR Josyer[8]:

> "*The Vymaanika Shastra, contrary to popular belief, is not a work of fiction. It presents a captivating array of Vimana capabilities, which align with what we now refer to as countermeasures. These include the ability to observe distant images on screens, hear sounds from afar, camouflage the Vimana as clouds or other objects, produce awe-inspiring sounds, and more. The text extensively explores the various types of Vimanas and their construction, some of which can function as both boats and submarines. It delves into topics such as atmospheric structure, aeronautical hazards and their prevention, and even offers guidance on diet and clothing for aviators*."

(The Vaimanika Shastra is a Sanskrit text with 300 shlokas in 8 chapters is recorded by Maharishi Bharadvaja, a Saptrishi from the vedic period)

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End Notes

[1] *Wikipedia*, s.v. “Hewitt-Sperry Automatic Airplane”, last modified 5 April 2022, at 20:12 (UTC), https://en.wikipedia.org/wiki/Hewitt-Sperry_Automatic_Airplane

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