Draft Study Material

DRONE OPERATOR: MULTIROTOR

(Qualification Pack: Ref. Id. AAS/Q6301)

SECTOR: AEROSPACE AND AVIATION

Grade XII

PSS CENTRAL INSTITUTE OF VOCATIONAL EDUCATION

(a constituent unit of NCERT, under Ministry of Education, Government of India)

Shyamla Hills, Bhopal- 462 002, M.P., India

http://www.psscive.ac.in

Preface

Vocational Education is a dynamic and evolving field, and ensuring that every student has access to quality learning materials is of paramount importance. The journey of the PSS Central Institute of Vocational Education (PSSCIVE) toward producing comprehensive and inclusive study material is rigorous and time-consuming, requiring thorough research, expert consultation, and publication by the National Council of Educational Research and Training (NCERT). However, the absence of finalized study material should not impede the educational progress of our students. In response to this necessity, we present the draft study material, a provisional yet comprehensive guide, designed to bridge the gap between teaching and learning, until the official version of the study material is made available by the NCERT. The draft study material provides a structured and accessible set of materials for teachers and students to utilize in the interim period. The content is aligned with the prescribed curriculum to ensure that students remain on track with their learning objectives.

The contents of the modules are curated to provide continuity in education and maintain the momentum of teaching-learning in vocational education. It encompasses essential concepts and skills aligned with the curriculum and educational standards. We extend our gratitude to the academicians, vocational educators, subject matter experts, industry experts, academic consultants, and all other people who contributed their expertise and insights to the creation of the draft study material.

Teachers are encouraged to use the draft modules of the study material as a guide and supplement their teaching with additional resources and activities that cater to their students' unique learning styles and needs. Collaboration and feedback are vital; therefore, we welcome suggestions for improvement, especially by the teachers, in improving upon the content of the study material.

Deepak Paliwal
Joint Director
PSSCIVE, Bhopal

Date: 3 March 2025

STUDY MATERIAL DEVELOPMENT COMMITTEE

Members

- Bikram Jyoti, *Scientist*, ICAR-Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal, Madhya Pradesh, India.

- Prerana Nashine, *Assistant Professor* (Contractual), Department of Curriculum Development and Evaluation Centre (CDEC) PSS Central Institute of Vocational Education (PSSCIVE), NCERT, Shyamla Hills, Bhopal – 462 002, Madhya Pradesh, India.

- Ramesh Sahani, *Scientist*, ICAR-Central Institute of Agricultural Engineering,

- Satya Prakash Kumar, *Scientist*, ICAR-Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal, Madhya Pradesh, India.

- Yogesh Rajwade, *Scientist*, ICAR-Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal, Madhya Pradesh, India.

Member-coordinator

Vinay Swarup Mehrotra, *Professor* and Head, Curriculum Development and Evaluation Centre & Centre for International Relationship, PSSCIVE, Bhopal, Madhya Pradesh.

Contents

Module 1	Safety Regulations and Procedures in Drone Operation

Module Overview

In module 1, "Safety Regulations and Procedures in Drone Operation" focuses on equipping essential knowledge and skills related to the safe and secure operation of drones, particularly multirotor drones. The module is structured to provide a thorough understanding of the safety regulations and guidelines that govern drone operations, as well as the protocols necessary to ensure the security of these devices.

Session 1, explores about the safety regulations and guidelines that must be adhered during drone operation, including the legal requirements set by aviation authorities like the Directorate General of Civil Aviation (DGCA) and the Federal Aviation Administration (FAA). This session will cover best practices for safe drone usage, from pre-flight checks to in-flight operations and post-flight procedures, while also examining real-world examples of safety breaches and their consequences.

Session 2 deals into the regulations and protocols designed to secure multirotor drones from potential threats. This includes cyber security measures, protecting communication channels, and ensuring data integrity. Strategies for configuring drones to prevent unauthorized access and tampering, along with understanding the legal implications of security lapses will also be explored.

Learning Outcomes

After completing this module, you will be able to:

- Describe the importance of adhering to multirotor drone safety regulations and online registration.
- Explain No Permission, No Take-off (NPNT) system.

- Identify procedures for obtaining necessary permissions before drone take-off.
- Demonstrate safety equipment categories effectively in different environments.

Module Structure

Session 1: Safety regulations and guidelines

Session 2: Multirotor Drone Security Regulations and Protocols

Session 1: Safety Regulations and Guidelines

Safety regulations are rules designed to prevent accidents, ensure safe operation, and minimize risks during drone flights and operations. Ensuring the security of multirotor drone operations requires strict regulations and protocols to maintain public safety and airspace integrity. These measures include mandatory registration and identification of drone operators and devices, ensuring accountability with unique IDs and verified credentials. Geo-fencing enforces no-fly zones, while the "No Permission, No Take-off" (NPNT) principle ensures prior approvals for specific operations.

To ensure the safe operation and security of multirotor drone flights, various regulations and measures have been put in place. These regulations come with several advantages and disadvantages, which are outlined as follows:

Advantages:

i. **Real-time Tracking and Accountability**: Remote identification systems enable tracking and accountability, reducing unauthorized drone activities.

ii. **Mitigation of Unauthorized Activities**: Counter-drone technologies help control and neutralize threats posed by unauthorized drones.

iii. **Effective Coordination**: Clear communication between operators, air traffic control, and authorities ensures swift responses to incidents.

iv. **Data Privacy Protection**: Adherence to data privacy guidelines, such as encryption and minimizing data collection, safeguards personal information.

v. **Safety and Responsibility**: Compliance with safety and technical standards, along with mandatory training, ensures safe drone operations.

vi. **Public Awareness**: Campaigns educate the public on responsible drone usage and encourage reporting of suspicious activities.

vii. **Legal Compliance**: Registration, licensing, and adherence to no-fly zones create a legally compliant environment for drone operations.

viii. **Safety Equipment**: Proper selection of safety equipment, like PPE and first aid kits, protects individuals from potential risks.

ix. **Ethical Data Handling**: Privacy considerations ensure that drone data is managed responsibly and ethically.

x. **Public Trust**: These measures foster public confidence in the safe integration of drones into society.

Disadvantages:

i. **Privacy Concerns**: Remote identification and tracking systems may raise privacy concerns for drone operators and individuals.

ii. **Cost**: Implementing counter-drone technologies and remote identification systems can incur significant costs.

iii. **Operational Restrictions**: Strict adherence to no-fly zones and legal requirements may limit operational flexibility for drone operators.

iv. **Training and Certification**: The requirement for mandatory pilot training and certification can be time-consuming and expensive.

v. **Complexity**: The integration of multiple technologies and protocols may lead to operational complexity for drone operators and authorities.

Drones are amazing inventions, but they come with responsibilities. Just as drivers must follow road rules, drone operators must adhere to sky regulations. To better understand these responsibilities, the following section discusses the essential safety regulations and guidelines for safe and responsible drone operation.

In the rapidly evolving field of drone technology, ensuring safety is paramount. Drones, have become increasingly popular for both recreational and commercial purposes, including aerial photography, agriculture, delivery services, and more. However, with this rise in usage comes the potential for accidents and misuse, making safety regulations essential.

Significance of Drone Safety Regulations

Drone safety regulations are critical for several reasons.

i. To protect people and property on the ground from potential harm caused by drone malfunctions or operator errors.
ii. To ensure that drones do not interfere with manned aircraft, thus preventing mid-air collisions that could have catastrophic consequences.
iii. To safeguard sensitive areas such as airports, military installations, and critical infrastructure from unauthorized drone activities.

Historical Context and Evolution

The development of drone safety regulations has evolved with technological progress and incidents emphasizing the need for stronger controls. Initially, regulations were simple, focusing on altitude and line-of-sight limits for hobbyists. As commercial drone use grew, agencies like the FAA and EASA introduced more detailed rules to ensure safety and compliance.

Major incidents, such as the 2018 Gatwick Airport disruption, highlighted the urgent need for stricter enforcement and better detection. These events prompted new measures, including mandatory drone registration, pilot certifications, and designated no-fly zones to protect sensitive areas.

Real-Life Examples and Regulatory Impact

Real-life examples illustrate the importance of drone safety regulations. The collision between a drone and a commercial aircraft in Canada in 2017 highlighted the risks of unregulated drone operations near airports. In response, regulatory agencies tightened restrictions and increased penalties for violations. Similarly, the use of drones for illegal activities, such as smuggling contraband into prisons, has prompted the development of counter-drone technologies and stricter laws.

Key Regulatory Bodies Overseeing Drone Operations in India

In India, the regulation of drones falls under the purview of several key governmental agencies, each with specific roles and responsibilities to ensure safe and lawful operation of unmanned aerial vehicles (UAVs). Understanding these regulatory bodies is crucial for both drone operators and stakeholders involved in the drone ecosystem. Key regulatory bodies overseeing drone operations in India is governed by:

i. Directorate General of Civil Aviation (DGCA)
The Directorate General of Civil Aviation (DGCA) is the primary regulatory authority responsible for civil aviation matters in India, including the regulation of drones. Its role includes:

- **Formulation of Regulations:** DGCA formulates and updates regulations governing the use of drones in India. These regulations cover aspects such as drone registration, pilot licensing, operational procedures, and airspace restrictions.

- **Issuance of Permits**: DGCA issues permits, approvals, and authorizations for drone operations in compliance with established regulations. This includes granting permissions for specific types of drone operations, such as aerial photography, surveying, and research.
- **Safety Oversight:** DGCA oversees safety standards and compliance with regulatory requirements to ensure that drone operations do not pose risks to manned aviation, public safety, or national security.

ii. Ministry of Civil Aviation (MoCA)

The Ministry of Civil Aviation (MoCA) plays a critical role in overseeing and directing the Directorate General of Civil Aviation (DGCA) regarding civil aviation matters, including drone regulations. MoCA is responsible for formulating national policies and guidelines that govern the integration of drones into the national airspace. Additionally, MoCA coordinates with other government agencies, such as the Ministry of Home Affairs and the Ministry of Defense, to address security concerns and ensure that drone regulations are harmonized across various sectors.

iii. Bureau of Civil Aviation Security (BCAS)

The Bureau of Civil Aviation Security (BCAS) is vital for securing civil aviation, including drone regulation. BCAS issues security clearances for drone operators and stakeholders involved in manufacturing, maintenance, and operations, especially near sensitive sites like airports. It also creates and enforces guidelines to mitigate risks of unlawful activities, including smuggling and terrorism.

iv. Ministry of Home Affairs (MHA)

The Ministry of Home Affairs (MHA) plays a significant role in drone regulation with a focus on national security. It assesses potential threats that drones may pose and provides guidance on measures to protect national security interests. This involves coordinating with other agencies to establish no-fly zones and impose restrictions on drone operations near sensitive installations, ensuring that drone activities do not compromise security.

v. Telecom Regulatory Authority of India (TRAI)

The Telecom Regulatory Authority of India (TRAI) is responsible for overseeing aspects of drone regulation related to spectrum and radio frequencies. Its role includes allocating and managing spectrum resources to ensure that drones have reliable communication and control systems.

TRAI's oversight helps prevent interference and ensures that the necessary frequency bands are available for safe and effective drone operations.

vi. State Police Departments

State Police Departments play a critical role in enforcing local regulations and ensuring compliance with drone laws at the state level. Their responsibilities include enforcing drone regulations within their jurisdictions, conducting inspections, and investigating unauthorized drone operations. Understanding the roles and responsibilities of these regulatory agencies is essential for navigating the legal and operational landscape of drone usage in India.

1. Introduction to digital sky platform

The Digital Sky Platform and guidelines prescribed by the Directorate General of Civil Aviation (DGCA) were implemented to the commercial utilization of drones or remotely operated aircraft. The Digital Sky Platform was introduced to establish a digital infrastructure for the registration and regulation of drone operations in Indian airspace **(Figure 1.1)**.

Figure 1.1: - Website view of Directorate General of Civil Aviation

The functioning of DGCA is explained as follows:

- The Digital Sky Platform is used for registering drones and obtaining flight permissions, ensuring regulated operation.
- Drones are classified by weight, with specific regulations for each category, and must have a Unique Identification Number (UIN).
- Commercial operators need a DGCA-issued Unmanned Aircraft Operator Permit (UAOP) for operations.

- No-fly zones like airports and military areas are restricted unless special approval is granted.
- Compliance with DGCA safety standards, such as anti-collision lights and geo-fencing, is required.
- Commercial pilots may need a Remote Pilot License (RPL), involving training and exams to demonstrate competency.

2. Airspace zones for flying drones

Airspace zones for drones are designated areas that regulate where drones can fly. Partitioning of Airspace for flying drones - Red Zone (flying not permitted), Yellow Zone (controlled airspace), and Green Zone (automatic permission). Respecting no-fly zones, which typically include airports, government buildings, and crowded public areas.
Just as road construction areas are marked with caution signs to warn of potential hazards, and fire extinguishers are accompanied by warning symbols, drone operations also involve segmented airspace zones **(Figure 1.2)**. Let us understand its significance.

Figure 1.2 Caution signals positioned alongside drone operations

In India, the Directorate General of Civil Aviation (DGCA) regulates drone operations, including the vertical and horizontal space dimensions for different drone flying zones. The primary regulatory framework is the Drone Rules, 2021, which delineates the airspace into different zones: Green, Yellow, and Red. Here are the key details regarding these zones:

The airspace designated for drone operations is divided into three distinct zones, each with specific regulations to ensure the safe and controlled use of drones

(Figure 1.3). These zones, namely the Red Zone, Yellow Zone, and Green Zone, are instrumental in managing drone activities while observing no-fly zones that typically encompass areas surrounding airports, government facilities, and densely populated public spaces.

Airspace Partitioning:

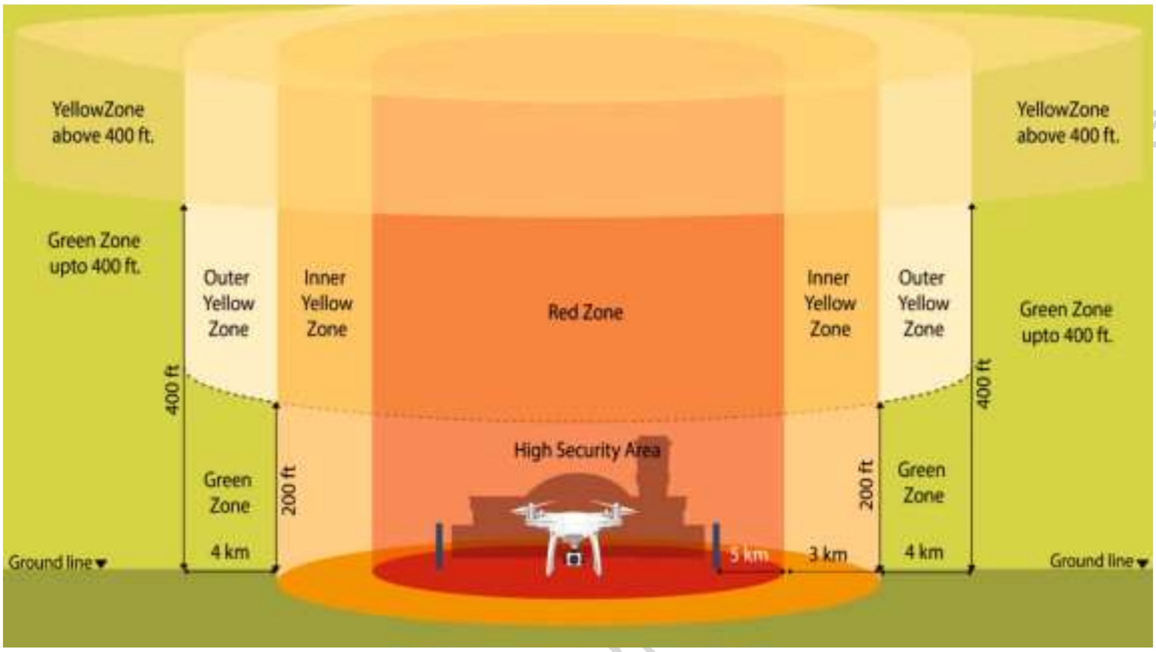

Figure 1.3: - Airspace partitioning: red, yellow and green

Red Zone (No-Fly Zone): The Red Zone designates areas where drone flights are strictly prohibited to ensure aviation safety and security. This includes sensitive locations such as airports, military installations, and government buildings. In these zones, drone operations are generally not permitted, making vertical and horizontal space considerations irrelevant as flights are prohibited. Permissions for operations in Red Zones are highly restricted and require special authorization from the Directorate General of Civil Aviation (DGCA) and other relevant authorities.

Additional Considerations

i. No-fly zones are areas where drones are prohibited from operating, regardless of altitude.
ii. These zones typically include areas near international borders, strategic sites, and other sensitive locations.
iii. Night operations are generally restricted, with drones allowed to fly after dark only if specific authorization is granted.

Operational Guidelines

Drones must always be operated within the Visual Line of Sight (VLOS) of the operator, ensuring that the drone remains visible at all times during flight. Additionally, operational guidelines vary based on the drone's Maximum Takeoff Weight (MTOW). For instance, Nano drones, weighing up to 250 grams, face fewer restrictions compared to Micro drones, which range from 250 grams to 2 kilograms, and larger drones. Each weight category has specific regulations to ensure safe and compliant operations.

Yellow Zone (Controlled Airspace): The Yellow Zone encompasses controlled airspace where drone operations are permitted but come with specific regulations and prerequisites. This zone typically includes areas near airports or other controlled airspace, demanding careful adherence to established guidelines. Vertical space in Yellow Zones varies depending on the proximity to airports and controlled airspace, while horizontal operations are generally allowed within a lateral distance of 8 to 12 kilometers from the airport perimeter. To operate in these areas, operators must obtain permission from the relevant Air Traffic Control (ATC) authority, ensuring compliance with all necessary regulations and safety protocols.

- **Inner Yellow Zone**:

i. Inner Yellow Zones refer to regions where drone flights are heavily controlled or prohibited due to security and safety concerns.
ii. These zones often include areas like airports, military bases, government buildings, and critical infrastructure that are vital for national security and public safety.
iii. Flying drones within these zones typically necessitates obtaining special permissions or clearances from the relevant authorities, such as aviation or defense agencies.
iv. Unauthorized drone flights in these zones can lead to legal penalties, fines, or criminal charges.
v. Violating drone restrictions in inner yellow zones may pose a risk to national security, leading to potential threats and safety hazards.
vi. Strict Enforcement: Due to the sensitive nature of these areas, enforcement of regulations is often strict, with possible surveillance and intervention by authorities.

- **Outer Yellow Zone**:

i. Buffer Area: Surrounds inner yellow zones, with more lenient restrictions.
ii. Regulated Operations: Drone flights in these areas are still subject to certain rules and guidelines.
iii. Restrictions: Includes altitude limits, distance from people/property, and airspace regulations.

iv. Permits and Notifications: Operators may need to obtain permits or notify authorities before flying.
v. Safety Focus: Rules are in place to avoid collisions with manned aircraft.

Green Zone (Automatic Permission): The Green Zone encompasses areas where drone operations are automatically permitted due to their low-risk nature and minimal restrictions. These zones provide a streamlined approval process for drone flights, requiring operators to adhere to general safety guidelines without needing specific prior permissions. In terms of vertical space, drones can operate up to 400 feet (120 meters) above ground level (AGL). Horizontally, the space is generally unrestricted, though in controlled airspace, operations are limited to up to 200 feet (60 meters) **Above Ground Level** (AGL) within a lateral distance of 8 to 12 kilometers from an operational airport's perimeter.

Respecting No-Fly Zones: No-fly zones around airports are crucial to prevent interference with manned aircraft **(Figure 1.4)**. Drones are prohibited from flying near airports without obtaining special permissions, mitigating potential risks associated with aviation activities.

Figure 1.4: - No Drone Zone caution sign

No-fly zones are often established around government structures or facilities for security reasons. Prohibiting drone flights in these areas helps safeguard the integrity and safety of sensitive locations.

Areas with large gatherings, such as events or crowded public spaces, are designated as no-fly zones. This restriction aims to reduce the risk of accidents or incidents in areas with high human density.

By abiding by these airspace partitions and respecting no-fly zones, authorities aim to balance the promotion of beneficial drone use with the imperative to protect public safety, national security, and conventional aviation operations. Drone operators must stay informed about and comply with these regulations to ensure responsible and lawful drone usage. It is crucial to remain updated on any revisions to these guidelines, as regulatory frameworks may evolve over time.

3. Rules and safety regulations for multirotor drone

Just like any other instrument, drones also require adherence to rules and safety precautions to ensure safe and responsible operation. It is necessary for the operator who is operating a multirotor drone entails more than just launching it into the sky; it requires a thorough understanding of regulations and safety protocols:

i. Drone operators must navigate airspace regulations and employ safety measures to prevent accidents and ensure responsible flight.
ii. Drone operators must handle their equipment with caution to prevent damage and accidents. Regular maintenance checks, proper battery handling, and thorough pre-flight inspections are essential safety practices,
iii. Drone operators must be aware of no-fly zones, restricted airspace, and privacy laws when planning a flight. Essentially, flying a drone in prohibited areas or invading someone's privacy can lead to legal repercussions and jeopardize public safety.
iv. Drone operators must be vigilant about potential hazards such as obstacles, adverse weather conditions, and electromagnetic interference that could compromise flight safety. Drone operators should maintain situational awareness and have contingency plans in places which are crucial for safe drone operation.
v. Responsible drone operation not only fulfils the operator's objectives but also contributes to the safety and well-being of the surrounding environment and community. By adhering to regulations and safety guidelines, drone operators can enjoy their flights with peace of mind, knowing that they are contributing to a culture of responsible and safe drone usage.

Guidelines and safety regulations govern the operation of multirotor drones, emphasizing responsible and secure usage. In the jurisdiction of multirotor drone operation, adherence to guidelines and safety regulations is paramount. These measures ensure not only the safety of those on the ground but also the integrity of airspace shared with manned aircraft.

i. Online Registration

Before taking flight, both drone operator and their drones must undergo online registration, a foundational step in promoting accountability and traceability. Pilots provide personal information and proof of identity, while drones are assigned unique identification numbers for easy tracking in case of incidents. Additionally, service providers offering drone-related services are also mandated to register

online, affirming their commitment to compliance with established regulations and safety standards. The flowchart for registration of drone is shown in **figure1.5**.

Figure 1.5: - Flow chart for registration of drone

ii. NPNT (No Permission, No Take-off)

An essential component of safe drone operation is the NPNT system, which stands as a safeguard against unauthorized flights. Drones equipped with NPNT technology cannot take off without securing necessary permissions for their intended flight path. This ensures that flights occur within authorized zones and under controlled circumstances, mitigating the risk of potential accidents or airspace violations.

iii. Safety Do's and Don'ts

Embedded within drone regulations are a set of safety do's and don'ts, serving as guiding principles for operators:

Do's:

- Respect designated no-fly zones, which typically include airports, government structures, and densely populated areas.
- Operate drones exclusively in approved and designated areas, adhering strictly to local regulations and guidelines.
- Keep the drone within visual range to ensure better control and situational awareness during flight operations.
- Adhere to altitude limits set by aviation authorities to prevent conflicts with manned aircraft operating in the same airspace.
- Prior to flight, verify weather conditions and abstain from flying in adverse weather such as strong winds or storms.

Don'ts:

- Avoid flying near airports, military zones, or other restricted areas without obtaining proper authorization **(Figure 1.6)**.
- Refrain from flying in conditions of low visibility where the drone may be difficult to see or control effectively.

- Abstain from flying over gatherings or populated areas to minimize the risk of accidents or injuries.
- Do not disrupt emergency operations, including firefighting or law enforcement activities, by flying drones in their vicinity.
- Uphold privacy laws and refrain from capturing images or videos of individuals without obtaining their explicit consent.
- The conscientious and secure operation of multirotor drones hinges on strict adherence to regulations and safety measures. Operators must stay informed about updates issued by aviation authorities, ensuring ongoing compliance and safety. By embodying these principles, drone enthusiasts contribute to a safer and more harmonious airspace environment for all.

Figure 1.6:- Safety tips

Activities

Activity 1: The group discussion on safety regulations for multirotor drone.

Materials Required: Whiteboard, Markers

Procedure:

- Introduce the discussion's goals and structure, emphasizing the importance of drone safety regulations.
- Present essential safety guidelines for multirotor drone operations, including flight restrictions and operator responsibilities.
- Engage participants with questions to explore safety regulations and encourage the sharing of personal experiences.
- Capture key discussion points and insights on the whiteboard for clarity and reference.
- Allow students to ask additional questions or express concerns regarding safety regulations.

Activity 2: DIY Drone Building and Testing Workshop

Materials Required: Wood, Thermocol, Plastic, Fiber, Propellers, Motors, Batteries, Glue, Tools (scissors, tape, etc.), Presentation slides, Whiteboard, Markers

Procedure:

- Begin with an overview of drone components and workshop objectives, emphasizing creativity and safety.
- Students select materials for their drone design and assemble the drone with guidance throughout the process.
- Once assembled, students test their drones, make adjustments to improve stability and performance, and showcase their completed drones, discussing design concepts and key learnings.

Check Your Progress

A. Multiple Choice Questions

1. What is the purpose of the Digital Sky Platform introduced by the Directorate General of Civil Aviation (DGCA) in India?
a) To promote recreational drone usage
b) To regulate commercial drone operations
c) To monitor weather conditions
d) To facilitate satellite launches

2. What is the primary function of the Digital Sky Platform?
a) Managing railway operations
b) Regulating drone-related activities
c) Promoting tourism
d) Conducting medical research

3. Drone operators in India are required to register their drones on the Digital Sky Platform to obtain which unique identifier?
a) GPS Coordinates
b) Serial Number
c) Unique Identification Number (UIN)
d) Operator's License

4. What does the Red Zone in airspace partitioning signify for drone operations?
a) Automatic Permission Zone
b) Controlled Airspace
c) No-Fly Zone
d) Unlimited Flying Zone

5. In which zone would drone operators typically need prior approvals and adherence to specified guidelines?
a) Green Zone
b) Yellow Zone
c) Red Zone
d) No-Fly Zone

6. What is NPNT in the context of drone safety regulations?
a) No Permission, No Take-off
b) National Protocol for Navigation Technology
c) Non-Profit No-Tolerance
d) New Pilot Navigation Tool

7. What is the purpose of "No Permission, No Take-off" (NPNT) for drones?
a) To limit the number of drone registrations
b) To ensure only experienced pilots operate drones
c) To prevent drones from taking off without necessary approvals
d) To encourage recreational drone use

8. What is the significance of "No-Fly Zones" around airports?
a) To promote drone racing events
b) To prevent interference with manned aircraft
c) To encourage night-time drone operations
d) To facilitate drone deliveries

9. What is one of the safety do's for multirotor drone operators?
a) Fly near airports for better connectivity
b) Fly in poor visibility conditions
c) Violate altitude limits for a better view
d) Maintain visual line of sight

10. What is one of the safety don'ts for multirotor drone operators?
a) Operate in approved and designated areas

b) Fly over crowds
c) Comply with altitude limits
d) Check weather conditions regularly

Session 2: Multirotor Drone Security Regulations and Protocols

Security protocols are enacted to ensure the safety of citizen in a country similarly, drone operators must follow specific guidelines to safeguard airspace and prevent potential security threats. These regulations include enforcing registration and identification of drones, explaining no-fly zones, obtaining authorization and permissions for flights, integrating remote identification systems, and implementing counter-drone measures when required.

Effective communication and coordination with relevant authorities, along with adherence to safety standards and data privacy guidelines, are essential to uphold security and integrity during drone operations. Drone operators must prioritize compliance and vigilance to maintain security and foster public trust in the responsible use of drone technology.

1. Security Regulations and Protocols for Safe Drone Operation

The establishment of regulations and protocols is integral to ensuring the security of drone operations. These measures are designed to mitigate risks, protect public safety, and prevent unauthorized or malicious drone activities. The following key aspects highlight the importance of regulations and protocols in securing drone operations:

i. **Strict Regulations**: Essential for the safe integration of drones into airspace.
ii. **Drone Registration**: Operators must register with authorities and obtain unique IDs.
iii. **No-Fly Zones**: Geo-fencing technology enforces no-fly areas to protect critical locations.
iv. **Prior Permissions**: Operators must seek approval for flights in controlled airspace or events.
v. **Remote Identification**: Enhances accountability and traceability of drone operations.
vi. **Counter-Drone Technology**: Addresses security threats from unauthorized or rogue drones.
vii. **Communication Protocols**: Ensures coordination between drone operators, air traffic, and authorities.

viii. **Data Privacy**: Guidelines protect personal data collected during drone operations.
ix. **Safety Standards**: Compliance with technical standards and mandatory pilot training ensures competence **(Figure 1.7)**.
x. **Public Awareness**: Campaigns educate the public on responsible drone use and reporting.

Figure 1.7: Security protocols

Registration and Identification

i. Drone operators and devices are mandated to register with aviation authorities, facilitating accountability and traceability.
ii. Each registered drone is assigned a unique identification number, aiding in identification and verification.
iii. Authorities verify the credentials and identity of drone operators to ensure compliance with regulations and enhance security measures.
iv. Clear separation of no-fly zones around critical areas such as airports and government facilities to prevent unauthorized drone entry.
v. Utilization of geo-fencing technology to establish virtual boundaries and prevent drones from entering restricted airspace, enhancing security and safety.

Authorization and Permissions:

i. Necessary permissions are required for specific drone operations, particularly in controlled airspace or during events, adhering to the "No Permission, No Take-off" (NPNT) principle.
ii. Drone operators must comply with the NPNT principle, ensuring that flights are authorized and permissible before take-off to mitigate security risks.

Remote Identification

Implementation of remote identification systems enables real-time tracking and identification of drones, enhancing accountability and facilitating rapid response to security incidents.

Counter-Drone Measures

Authorization for employing counter-drone technology to detect and mitigate security threats posed by unauthorized drones, with formulated protocols for responding to rogue or malicious activities.

Communication and Coordination

Clear communication protocols between drone operators, air traffic control, and relevant authorities are established to facilitate coordination and swift responses to security incidents, ensuring effective management of airspace.

Data Privacy and Protection:

Implementation of guidelines to safeguard personal data collected during drone operations, adhering to data privacy regulations to protect individuals' rights and privacy, enhancing trust and accountability.

Safety and Technical Standards:

Compliance with safety and technical standards established by aviation authorities ensures the airworthiness of drones, promoting safe and responsible operation.

Training and Certification:

Mandatory training and certification for drone pilots ensure competence and awareness of regulations, with ongoing education on evolving security protocols and best practices.

Public Awareness and Education:

Public awareness campaigns educate individuals about responsible drone use and potential security issues, encouraging reporting of suspicious activities to enhance overall security.

2. Legal requirements for drone registration, pilot license, and certification

i. **Drone Registration**
In India drone operators are typically obligated to register both themselves and their drones with DGCA Registration usually involves submitting personal details, contact information, and, in some cases, proof of identity.

ii. **Pilot License or Certification**
Depending on drone type and weight, operators may need to acquire a drone pilot's license. Drone pilot licenses often necessitate passing exams covering aeronautical knowledge, airspace regulations, and drone operation.

iii. **Certification for Commercial Operations:**
Commercial drone operators may require specific certifications, such as an Unmanned Aircraft Operator Permit (UAOP) in certain countries. Certification processes may include demonstrating operational procedures, safety measures, and compliance with particular regulations.

iv. **Operational Certificates and Approvals:** It is also mandatory to have operational certificates for specific types of drone activities, especially commercial or specialized operations. Certificates may involve approvals for particular types of operations, such as beyond visual line of sight (BVLOS) flights.

v. **Training Requirements:** Drone operators might be required to undergo training programs offered by approved institutions. Training programs cover various aspects of safe drone operation, including airspace understanding, emergency procedures, and compliance with regulations.

vi. **Insurance Requirements:** Certain jurisdictions may stipulate liability insurance for drone operators to cover potential damages or accidents resulting from drone operations. Insurance requirements can vary based on the intended use and the size of the drone.

vii. **Adherence to No-Fly Zones:** Compliance with no-fly zones is generally required, including areas around airports, government structures, and other sensitive locations. Violating no-fly zones may lead to legal repercussions.

viii. **Remote Identification Systems:** Some regions may require drones to incorporate remote identification systems to enhance accountability and traceability.

ix. **Compliance with Safety Standards:** Compliance with safety and technical standards set by aviation authorities, encompassing features such as anti-collision lights and geo-fencing capabilities. It is crucial to note that regulations are subject to change, and new requirements may be introduced. Therefore, drone operators should regularly check with local aviation authorities for the latest updates and adhere to the specific regulations applicable in their region.

3. **Safety equipment**

Safety equipment encompasses specialized gear and devices designed to safeguard individuals from potential hazards and minimize the risk of injury or harm across diverse environments. The selection of safety equipment is contingent upon the nature of the activity or workplace.

The following are common categories of safety equipment:

i. Essential Personal Protective Equipment (PPE) for Workplace Safety

Hard hats are designed to protect the head from falling objects or impacts, while safety glasses or goggles shield the eyes from debris, chemicals, or other hazards. Ear protection, such as muffs or plugs, reduces exposure to loud noises. Respirators, including masks and filters, safeguard against airborne contaminants. Additionally, gloves come in various types for hand protection, such as cut-resistant, chemical-resistant, and heat-resistant options, depending on the specific risks involved **(Figure1.8)**.

Figure 1.8 Personal protective equipment (PPE)

ii. First Aid Kit

Proper safety equipment, including first aid kit **(Figure 1.9)**, guardrails, and barriers, is essential for preventing accidents and maintaining a secure work environment. Regular upkeep and awareness of industry-specific requirements ensure safety.

Figure 1.9: First aid kit

4. **Real-Time Remote Identification for Drone Verification**
Deploying remote identification technologies for drones is a crucial measure aimed at bolstering safety, accountability, and public confidence in drone operations. This technology enables the instantaneous identification of drones, offering authorities and the public the means to validate drone identity. The implementation process involves several key components:

i. **Remote Identification System Components**

- **Unique Identification and Broadcasting**: Drones are assigned unique IDs and equipped with broadcast modules that transmit identification information during operations.

- **Real-Time Monitoring**: Specialized receivers capture these signals, enabling real-time tracking of drone activities by authorities and other monitoring systems.

- **Verification and Cross-Referencing**: Authorities verify drone identities by cross-referencing IDs with databases linking them to registered owners for immediate confirmation.

- **Airspace Coordination and Public Access**: Data integration into air traffic management systems improves coordination between manned and unmanned aircraft, with limited public access to drone identifiers.

- **Regulatory Compliance and Security**: Remote identification ensures compliance with safety standards and airspace regulations, supporting security measures while safeguarding privacy and working toward global standards.

5. Data privacy

Preserving data privacy within the realm of drone operations involves safeguarding the personal information and data gathered by drone during their missions. Drones, equipped with various sensors and cameras, may capture sensitive information, making it imperative to prioritize individual privacy. Key considerations for data privacy in the drone industry include **(Flow chart 1.1)**:

i. **Data Collection and Purpose Limitation**: Securing informed consent from individuals when collecting potentially identifying data. Clearly articulating the purpose of data collection and ensuring alignment with legal and ethical standards.

ii. **Data Security Measures**: Implementing encryption protocols to secure data during transmission and storage. Employing robust security measures to prevent unauthorized access.

iii. **Minimization of Data**: Collecting only the essential data needed to fulfill the intended purpose. Avoid collecting unnecessary or sensitive information.

iv. **User Rights and Control**: Affording individuals, the right to access their data and rectify inaccuracies. Granting users control over the usage and processing of their data, including opt-out options.

v. **Geolocation Data Privacy**: Handling geolocation data responsibly to prevent potential privacy intrusions. Clearly communicating the use of location data and obtaining necessary consent.

vi. **Privacy by Design**: Incorporating privacy features into drone design and operations from the project's inception. Prioritizing privacy as an integral aspect of technological development.

vii. **Data Anonymization and De-Identification**: Anonymizing or de-identifying data to shield the identities of individuals captured in drone footage. Ensuring that data cannot be readily traced back to specific individuals.

viii. **Transparency and Communication**: Maintaining transparent and easily understandable privacy policies detailing how drone data will be handled. Providing accessible information to the public about drone operations and data practices.

ix. **Legal Compliance**: Complying with relevant data protection laws and regulations, such as local privacy legislation. Staying abreast of evolving legal standards and adapting practices accordingly.

x. **Data Breach Response**: Establishing protocols to promptly respond to any data breaches involving drone-collected information. Notifying affected individuals and relevant authorities following data breach notification requirements.

Upholding data privacy in drone operations is pivotal for cultivating public trust and ensuring ethical practices.

[Data Collection and Purpose Limitation]
↓
[Data Security Measures]
↓
[Minimization of Data]
↓
[User Rights and Control]
↓
[Geolocation Data Privacy]
↓
[Privacy by Design]
↓
[Data Anonymization and De-Identification]
↓
[Transparency and Communication]
↓
[Legal Compliance]
↓
[Data Breach Response]

Flow chart 1.1: Data privacy steps

Activities

Activity 1: Design a remote identification system for drones

Materials Required: Paper, pens, markers, and presentation materials (e.g., whiteboard or projector)

Procedure:

1. **Introduction:** Explain the importance of remote identification in drone safety and regulatory compliance to all students.

2. **Group Work:** Divide students into small groups and task each group with designing a remote identification system for drones. Encourage them to discuss essential components and features, then sketch their designs on paper.

3. **Presentation and Feedback:** Each group presents their design, explaining their approach and considerations. Facilitate a feedback session and group discussion to explore different ideas and deepen understanding of remote identification systems.

Activity 2: Implement no-fly zones and geo-fencing for drones

Materials Required: Computers with mapping software, internet access, digital maps, and drone simulation software

Procedure:

1. **Introduction and Mapping:** Begin with an overview of no-fly zones and the importance of geo-fencing for drone safety. Students will identify and mark restricted airspace on digital maps, highlighting locations such as airports and government facilities.

2. **Integration of Geo-Fencing Technology:** Guide participants to use mapping software to implement geo-fencing technology, creating virtual boundaries around the identified no-fly zones. Explain how this technology prevents drones from entering restricted areas.

3. **Database Management and Simulation:** Demonstrate how to update the geo-fencing database to reflect changes in restricted zones. Have students run simulations to test the effectiveness of the geo-fencing, ensuring drones respond correctly by staying out of no-fly zones.

4. **Feedback and Review:** Discuss the outcomes, challenges encountered, and best practices for maintaining an up-to-date and effective geo-fencing system.

Check Your Progress

A. Multiple Choice Questions

1. What is the primary purpose of deploying remote identification technologies for drones?
a) Enhancing drone speed and agility

b) Bolstering safety, accountability, and public confidence
c) Extending drone battery life
d) Improving drone camera resolution

2. Which component of the remote identification system continuously transmits identification information during drone operations?
a) Distinct identifiers
b) Broadcast modules
c) Receivers
d) Live monitoring systems

3. How do authorities verify drone identification information?
a) By visually inspecting the drone
b) By cross-referencing transmitted identification with registered owner information
c) By listening to identification signals
d) By accessing the drone's flight log

4. What type of information is typically accessible to the public through remote identification technologies?
a) Detailed flight paths of drones
b) Full personal details of drone owners
c) Drone serial numbers or generic identifiers
d) Live video feeds from drones

5. How does remote identification technology integrate with existing air traffic management systems?
a) By controlling drone operations remotely
b) By providing real-time weather updates to drones
c) By seamlessly integrating identification signals into air traffic management systems
d) By automatically landing drones in case of emergencies

6. Why do aviation authorities mandate the use of remote identification technologies for specific drone operations?
a) To increase drone sales
b) To ensure compliance with airspace regulations and safety standards
c) To enhance drone battery life
d) To improve drone camera resolution

7. What capability does remote identification technology provide authorities in the event of incidents or security concerns involving drones?
a) The ability to remotely control drones
b) The capability to confiscate drones
c) The capability to promptly identify the drone operator for necessary action
d) The ability to jam drone signals

8. What aspect is pivotal in designing remote identification systems to strike a balance between accountability and individual privacy?
a) Increasing the range of identification signals
b) Implementing data protection measures
c) Enhancing drone maneuverability
d) Developing faster drones

9. What are ongoing efforts directed toward in the realm of remote identification technologies?
a) Increasing drone size
b) Reducing drone noise levels
c) Establishing global standards and interoperability
d) Developing drones for recreational purposes

10. What is the primary conclusion regarding the implementation of remote identification technologies for drones?
a) It undermines safety and security measures
b) It fosters a secure and responsible drone ecosystem
c) It increases privacy concerns
d) It leads to a decrease in drone usage

Module 2	Emergency Procedures in Drone Flying

Module Overview

Module 2 on "Emergency Procedures in Drone Flying" is designed to provide the critical knowledge and skills required to handle emergency situations that may arise during drone operations. This module emphasis the importance of being prepared for unexpected events and equips learners with the necessary procedures to respond effectively to emergencies, ensuring the safety of both the drone and its surroundings.

Session 1, focus on general emergency procedures applicable to various scenarios in drone operations. This session will cover the fundamental steps to be taken in case of emergencies such as loss of control, technical malfunctions, adverse weather conditions, and other unforeseen events. This session explores different types of emergencies, how to assess the situation, and the immediate actions needed to mitigate risks.

Session 2 specifically deals with emergency procedures in drone flying, providing detailed guidance on how to handle in-flight emergencies. This session will delve into critical topics such as executing emergency landings, dealing with mid-air collisions, and managing power failures. It will also cover the importance of maintaining calm and following protocol during high-pressure situations to minimize damage and ensure safety.

Learning Outcomes

After completing this module, you will be able to:

- Identify common drone hazards, such as obstacle collisions and GPS signal loss.
- Demonstrate critical actions like Return-to-Home (RTH) and controlled landings to manage malfunctions.
- Describe aviation standards, pre-flight checks, and no-fly zones for safe drone operations.

- Define the importance of regular training and risk assessment to ensure safety and build public trust.

Module Structure

Session 1: General Emergency Procedures for Drone Operations

Session 2: In-Flight Emergency Procedures and Crisis Management

Session 1: General Emergency Procedures for Drone Operations

General emergency procedures for drone operations involve steps to handle control loss, technical malfunctions, weather issues, and unforeseen events.

1. Flight hazards around structures

Navigating unmanned aerial vehicles (UAVs) or drones around structures involves considering potential flight hazards that could pose risks to safe operations. These challenges necessitate careful attention from operators to ensure the well-being of the drone and prevent accidents. Here are various common flight hazards associated with structures:

- **Obstacle Avoidance**: Drones must maneuver around tall structures to prevent collisions and maintain a safe distance. Unpredictable wind patterns near buildings can impact the stability of the drone.
- **Electromagnetic Interference**: Power lines and electrical infrastructure may cause electromagnetic interference, affecting the navigation systems of the drone. Proximity to high-voltage power lines poses risks of electrical interference and potential damage.
- **Wire Hazards**: Flying drones in proximity to cables, wires, or similar obstacles requires caution. Entanglement with cables can result in loss of control and potential damage to the drone.
- **Restricted Airspaces**: Operating drones near airports, helipads, or restricted airspaces presents significant hazards. Strict regulations govern these areas to prevent interference with manned aviation.

- **Building Drafts and Wind Effects**: Tall buildings can generate wind drafts and turbulence affecting the drone's stability. Sudden changes in wind patterns around structures can pose challenges to drone control.

- **Collision Risks**: Risks of collisions increase when drones fly at low altitudes near antennas or rooftop structures. Operators must be mindful of the surrounding environment to prevent accidents.

- **Communication Signal Interruption**: Urban environments with dense structures may lead to signal interruptions or communication loss between the drone and its operator. Signal reflection and absorption by buildings can impact remote control and telemetry.

- **GPS Signal Issues**: Tall buildings in urban canyons can obstruct GPS signals, affecting the accuracy of the drone's navigation. Positional errors may occur, potentially leading to control challenges.

- **Bird Strikes**: Structures like towers or bridges may attract birds, posing a risk of bird strikes. Collisions with birds can result in damage to the drone, compromising its safety.

Maintaining safe and responsible drone operations necessitates an understanding of flight hazards around structures. Drone operators should be vigilant of their surroundings, adhere to regulatory guidelines, and leverage obstacle avoidance systems to enhance safety when flying near various structures.

2. Common drone emergencies

Navigating drones involves the possibility of encountering unexpected challenges and emergencies. Familiarizing oneself with common drone emergencies is essential for operators to respond promptly and effectively. Here are typical drone emergencies:

- **Loss of Signal (Flyaway)**: It occurs when the drone loses communication with the remote controller, leading to unintended drift or unpredictable flight. Activate the Return-to-Home (RTH) function, directing the drone to return to its takeoff point. Use manual control inputs to regain command if RTH is unsuccessful.

- **Low Battery Situation**: Drones approaching low battery levels may trigger an automatic return-to-home or initiate a landing at their current location. Monitor battery levels during flight and initiate a return-to-home when levels are low. Promptly land the drone to prevent an uncontrolled descent.

- **GPS Signal Loss**: Loss of GPS signal can impact the drone's navigation accuracy, particularly in areas with signal interference. Fly the drone manually with caution, as automated features may be affected. Ascend to a higher altitude to restore a stable GPS connection.

- **Motor or Propeller Failure**: Mechanical issues like motor failure or propeller damage can compromise the drone's stability and control. Land the drone immediately in a safe location to prevent further damage. Inspect and replace damaged components before resuming flight.

- **Obstacle Collision**: Drones may collide with obstacles such as trees, buildings, or structures, resulting in potential damage. Engage obstacle avoidance systems if available. Land the drone for a thorough inspection to assess any damage.

- **Weather Challenges**: Adverse weather conditions like strong winds, rain, or storms pose a risk to drone operations. Avoid flying in unfavorable weather conditions. Land the drone immediately if weather conditions worsen during flight.

- **Compass Calibration Issues**: Incorrect compass calibration can lead to navigation errors and erratic flight behavior. Recalibrate the drone's compass following the manufacturer's instructions. Avoid flying in areas with strong magnetic interference.

- **Remote Controller Malfunction**: Malfunctions in the remote controller can result in a loss of control over the drone. Attempt to regain control through manual inputs. Safely land the drone and address or replace the malfunctioning remote controller.

- **In-flight System Errors**: System errors or software glitches during flight can lead to unexpected behavior. Follow the drone's user manual for troubleshooting steps. Land the drone safely and address any software or firmware issues.

- **Bird Attacks**: If birds are present in the area, land the drone immediately to avoid potential collisions. Flying near bird nesting areas should be done with caution to prevent disturbing the birds. Always assess the surroundings before flying to ensure bird safety and minimize risks. Prioritize avoiding areas where bird activity is high to ensure safe drone operations.

- Regular maintenance, pre-flight checks, and adherence to safety guidelines are essential for preventing emergencies and ensuring the longevity of drone equipment.

3. Recommended emergency responses

Recommended responses for drone emergencies are crucial to guide operators in effectively managing unexpected situations and ensuring the safety of both the drone and its surroundings. Here are suggested measures for common drone emergencies:

- **Loss of Signal (Flyaway)**: If available, activate the Return-to-Home (RTH) function. Use manual control inputs to regain command if RTH is unsuccessful. Monitor the drone's location and take evasive actions to avoid obstacles.

- **Low Battery Situation**: Initiate a controlled return-to-home for a safe landing. Avoid flying to the maximum range to allow for a safe return when battery levels are low. Land the drone promptly to prevent an uncontrolled descent.

- **GPS Signal Loss**: Fly the drone manually with caution, considering the potential impact on navigation accuracy. Ascend to a higher altitude to restore a stable GPS connection. Exercise caution when relying solely on automated features in areas with known signal interference.

- **Motor or Propeller Failure**: Land the drone immediately in a safe location to prevent further damage. Inspect and replace damaged components before resuming flight. Avoid attempting maneuvers that strain the remaining motors.

- **Obstacle Collision**: Engage obstacle avoidance systems if available. Land the drone for a thorough inspection to assess any damage. Refrain from flying in environments with a high risk of collisions.

- **Weather Challenges**: Avoid flying in adverse weather conditions, including strong winds, rain, or storms. Land the drone immediately if weather conditions worsen during flight. Monitor weather forecasts before and during the flight.

- **Compass Calibration Issues**: Recalibrate the drone's compass following the manufacturer's instructions. Avoid flying in areas with strong magnetic interference. Verify proper calibration before each flight.

- **Remote Controller Malfunction**: Attempt to regain control through manual inputs. Safely land the drone and address or replace the malfunctioning remote controller. Consider carrying a backup remote controller if possible.

- **In-flight System Errors**: Follow the drone's user manual for troubleshooting steps. Land the drone safely and address any software or firmware issues. Keep software and firmware updated to minimize the risk of errors.

- **Bird Attacks**: Land the drone immediately if birds are present to avoid collisions. Exercise caution and avoid flying near bird nesting areas to ensure safety. Consider adjusting the flight path or altitude to minimize bird encounters.

This emergency should be integrated into the standard operating procedures of drone operators. Regular training, pre-flight checklists, and a comprehensive understanding of the drone's capabilities and limitations contribute to effective emergency response strategies.

4. Do's and don'ts during flight emergency

Do's:

- **Maintain Composure**: Keep a level head to make clear decisions and handle the situation effectively.

- **Activate Return-to-Home (RTH)**: RTH is a feature in the drone that is activated when the RTH button is pressed, prompting the drone to automatically return to its designated home point. This function is typically triggered in situations like signal loss, low battery, or other emergencies, ensuring the drone returns safely without further user input. RTH is a crucial safety feature designed to prevent the drone from flying out of range or getting lost.

- **Ensure Safe Landing**: Aim for a safe landing spot away from people, buildings, and obstacles.

- **Warn Nearby Individuals**: Alert nearby individuals if the drone poses a potential risk to their safety.

- **Monitor Battery Levels**: Keep an eye on battery levels and land the drone before it runs out of power.

- **Adhere to Regulations**: Follow local drone regulations and guidelines, especially in emergency scenarios.

- **Assess Environmental Factors**: Consider factors like wind, obstacles, and weather conditions when responding to emergencies.

- **Follow Manufacturer's Procedures**: Follow any emergency procedures outlined by the drone manufacturer.
- **Report Incidents**: Report any incidents involving property damage or public safety risks to the relevant authorities.

Don't:

- **Fly Over Crowded Areas**: Avoid flying over crowded areas during emergencies to prevent potential harm.
- **Ignore Warnings**: Respond immediately to any warning signals or indications of trouble with the drone.
- **Attempt Risky Maneuvers**: Refrain from risky flight maneuvers that could worsen the situation.
- **Lose Sight of the Drone**: Keep the drone within your line of sight, especially during emergencies, to maintain control.
- **Delay Action**: Act promptly to address emergencies, as delays could lead to further complications.
- **Neglect Safety Protocols**: Always prioritize safety protocols, even in emergency situations.
- **Enter Restricted Areas**: Avoid flying in restricted airspace or prohibited areas, especially during emergencies.
- **Endanger yourself or Others**: Avoid endangering yourself or others by attempting risky rescues.
- **Lose Communication**: Maintain communication with the drone to assess the situation and respond effectively.

Activities

Activity 1 : Drone safety and emergency response training

Materials Required: Multirotor drones, pre-flight inspection checklists, communication devices, safety equipment, emergency scenario guides

Procedure:

- **Safety Briefing and Pre-Flight Inspection:** Gather students, emphasize safety, and conduct a detailed safety briefing. Demonstrate the pre-flight inspection checklist for drones and allow participants to practice.
- **Emergency Scenario Simulation:** Create and simulate various emergency situations, assigning roles like drone operator, safety observer, and communication coordinator. Teach appropriate response protocols, such as regaining control and executing safe landings.
- **Hands-On Flight Training and Debriefing:** Provide practical flight training to practice emergency procedures, offering supervision and feedback. Conclude with a debriefing session to review procedures, address questions, and distribute a summary of key concepts.

Check Your Progress

A. Multiple Choice Question

1. What is the recommended response for a drone experiencing a loss of signal (flyaway)?
a) Continue the flight as planned
b) Activate Return-to-Home (RTH) function if available
c) Descend rapidly to regain signal
d) Increase the drone's speed to overcome signal loss

2. During a low battery situation, what action should be taken to ensure a safe landing?
a) Fly the drone to its maximum range
b) Initiate a controlled return-to-home (RTH)
c) Ignore the low battery warning and continue flying
d) Increase the altitude to conserve battery power

3. What is the recommended response when a drone experiences GPS signal loss?
a) Fly at maximum speed to restore signal
b) Descend rapidly to regain signal
c) Ascend to a higher altitude with caution
d) Ignore the GPS signal loss and continue flying

4. If a drone encounters a motor or propeller failure, what action should the operator take?
a) Attempt complex maneuvers to test remaining motors
b) Land the drone immediately in a safe location
c) Increase altitude to reduce strain on the remaining motors

d) Ignore the issue and continue flying

5. What is the recommended response when facing an obstacle collision during flight?
a) Engage obstacle avoidance systems if available
b) Increase speed to quickly pass the obstacle
c) Fly closer to obstacles for a better view
d) Ignore obstacles and continue the flight

6. During adverse weather conditions, what action should drone operators take?
a) Increase flight altitude to avoid weather effects
b) Avoid flying in unfavorable weather conditions
c) Land the drone and wait for weather improvement
d) Fly at maximum speed to quickly pass through the weather

7. What is the suggested response for compass calibration issues during flight?
a) Ignore the calibration issues and continue flying
b) Recalibrate the drone's compass following the manufacturer's instructions
c) Fly the drone manually at high speeds to resolve the issue
d) Descend rapidly to minimize the impact of calibration issues

8. If a remote controller malfunctions during drone flight, what should the operator do?
a) Ignore the malfunction and continue flying
b) Attempt to regain control through manual inputs
c) Increase the drone's altitude to improve remote control
d) Fly the drone towards the malfunctioning remote controller

9. What is the recommended response to in-flight system errors during drone operations?
a) Ignore the errors and continue flying
b) Land the drone safely and address any software or firmware issues
c) Increase the drone's speed to override system errors
d) Reset the drone mid-flight to clear system errors

Session 2: In-Flight Emergency Procedures and Crisis Management

Imagine a situation where drone is experiencing a sudden technical malfunction while flying over a populated area. In such a scenario, a pilot's adept execution of emergency procedures, like initiating an emergency landing in a designated zone, can prevent potential harm to people or property on the ground. This underscores the significance of comprehensive training and a deep understanding of a drone's capabilities to foster a culture of responsible and safe drone operation.

While flying a drone flying, strict adherence to emergency procedures is crucial for safeguarding both operators and the general public. Drone pilots must be well-acquainted with protocols for responding to unforeseen circumstances, such as equipment glitches, adverse weather conditions, or unauthorized intrusions into airspace. Quick and precise actions may involve implementing emergency landing maneuvers, activating return-to-home functionalities, or executing emergency shut-down procedures.

Moreover, operators should possess the ability to assess potential risks and make prompt decisions to mitigate any hazards encountered during flight. Thorough pre-flight planning, which includes identifying suitable emergency landing zones and awareness of no-fly zones, contributes to heightened preparedness and reduces the likelihood of critical incidents.

1. Drone emergency and handling procedure

Drone emergency and handling procedures are predefined protocols crucial for ensuring the safety of both the drone and its surroundings during unexpected situations.

- **Emergency Landing Protocols:** Drone operators are trained to respond to low battery levels, signal loss, or technical malfunctions by executing emergency landing procedures. This involves identifying a safe landing area and conducting a controlled descent.
- **Return-to-Home (RTH) Activation:** Drones often feature RTH functions, automatically directing the drone back to its takeoff point in cases of signal loss or critical issues.
- **Emergency Shut-Down:** In situations requiring immediate intervention, such as loss of control, operators are instructed on how to swiftly execute an emergency shut-down to cease all drone functions promptly.
- **Risk Assessment:** Continuous risk assessment during flight is emphasized, with operators actively identifying and responding to potential hazards like changing weather conditions, nearby obstacles, or the presence of other aircraft.

- **Pre-flight Checks:** Thorough pre-flight checks form a crucial step, involving inspections of drone components, calibration of sensors, and verification of communication links. These checks aim to address potential issues before takeoff.
- **No-Fly Zone Awareness:** Operators are expected to understand and adhere to no-fly zones, which may encompass restricted airspace, private property, or other sensitive areas, to prevent legal and safety complications.
- **Continuous Training:** Regular training sessions are essential to keep operators updated on the latest technologies, regulations, and best practices. This ongoing education ensures that operators remain proficient in handling emergencies and effectively mitigating risks.

By following these comprehensive procedures, drone operators contribute to responsible and safe drone technology use, reducing the likelihood of accidents and maintaining compliance with aviation regulations.

2. Emergency procedures during loss of link

Emergency procedures for a loss of link refer to the steps drone operators take when communication between the drone and remote controller is lost. This is important because it can lead to loss of control and safety hazards. The following outlines common emergency procedures for a loss of link:

- **Engage Return-to-Home (RTH):** Many drones are equipped with an automatic Return-to-Home function. In cases of a lost link, activating RTH ensures the drone autonomously returns to its takeoff location. It is essential to establish a clear and safe home point before initiating flight.

- **Initiate Emergency Landing:** If RTH is impractical or the drone's whereabouts are uncertain, initiating an emergency landing becomes necessary. This involves carefully guiding the drone to a secure landing spot, considering terrain and potential obstacles.

- **Maintain Visual Line of Sight (VLOS):** In the absence of a reliable link, maintaining visual line of sight with the drone becomes crucial. This allows the operator to observe the drone's behavior, evaluate its surroundings, and potentially guide it manually to a safe landing.

- **Monitor Altitude:** Tracking the drone's altitude is crucial during a loss of link. This information helps prevent collisions with obstacles or terrain. Operators should prioritize maintaining a safe altitude until the link is reestablished or a secure landing is achieved.

- **Activate Emergency Shut-Down:** In extreme cases where the drone is unresponsive and poses a risk, activating the emergency shut-down feature becomes necessary. This action halts all drone functions, preventing further unintended movements.

- **Attempt Reconnection:** Operators should make efforts to re-establish the link by adjusting the location, altering the orientation of the remote controller's antenna, or troubleshooting any potential interference issues. Reconnecting may restore control over the drone.

- **Communicate with nearby Authorities:** If the drone is operating in areas with other air traffic or near populated regions, operators should consider communicating the situation to local aviation authorities or relevant stakeholders to ensure overall safety.

- **Review and Improve Procedures:** Following a loss of link incident, it is crucial to assess the circumstances leading to the communication failure and update procedures accordingly. This continuous improvement process enhances preparedness for subsequent flights. Maintaining awareness of the situation, being acquainted with the drone's specific capabilities, and undergoing regular training on loss of link scenarios are fundamental aspects of effective emergency procedures in such circumstances.

3. Emergency procedures during loss of power

Emergency procedures in the event of a power loss during drone operation are essential for mitigating potential risks and ensuring the safety of the drone, its surroundings, and any individuals nearby. The following key emergency procedures should be followed:

- **Initiate Emergency Landing:** Immediately respond to a power loss by initiating an emergency landing. Guide the drone in a controlled descent to prevent crashes and minimize potential damage.

- **Choose a Safe Landing Area:** Quickly assess the surroundings and choose a landing area that is safe, avoiding populated regions, water bodies, and obstacles to prevent harm to people and property.

- **Glide and Descend Safely:** Utilize any available residual power to guide the drone in a controlled descent, minimizing impact force upon landing.

- **Avoid Obstacles:** Actively navigate the drone away from obstacles such as buildings, trees, or other structures during the emergency descent to reduce the risk of collisions and potential damage.

- **Execute Emergency Shut-Down:** If possible, execute the emergency shut-down procedure to completely power off the drone, preventing unintended movements or further complications after landing.

- **Assess for Damage:** Carefully assess the drone for any damage post-landing, checking structural integrity, propellers, and other components. If damage is significant, suspend operations until repairs are completed.

- **Retrieve Drone Safely:** Retrieve the drone safely and promptly after landing to minimize potential hazards to people or property in the vicinity.

- **Report and Document:** In cases of significant consequences or potential property damage resulting from the power loss, document the incident and report it to relevant authorities or regulatory bodies as needed.

- **Investigate and Prevent:** Conduct a thorough investigation into the cause of the power loss after the emergency. Use the findings to prevent similar incidents through improved procedures or equipment maintenance.

- **Continuous Training:** Regularly undergo training on emergency procedures, including simulated power loss scenarios, to ensure preparedness and responsiveness in real-life situations.

By following these emergency procedures during a power loss, drone operators can effectively minimize the potential impact of such incidents, prioritizing the safety of the drone and its surroundings.

4. Emergency procedures during flying

Emergency procedures are essential for drone operators to manage various situations during drone flights and ensure safety. Here are specific procedures for common scenarios:

- **Fly Away:** In a fly-away scenario, quickly switch to manual control and disable any autonomous flight modes. Use the remote controller to attempt to regain control of the drone. Keep a close watch on the drone's behavior and altitude during this process. Prompt action is essential to ensure safety and prevent further issues.

- **Loss of GPS signal**: necessitates a shift to manual mode if required, relying on visual piloting and alternative sensors for stability, while considering emergency landing options in safe areas.

- **Collisions**: To avoid collisions, activate obstacle avoidance systems if available, perform emergency maneuvers, and closely monitor feedback from the drone's sensors, conducting a thorough post-collision inspection for damage.

- **Loss of communication Link**: In the case of a communication link failure, efforts should be made to re-establish communication, with the option to activate Return-to-Home (RTH) procedures and follow emergency landing protocols while maintaining visual contact.

- **Battery failure:** It requires initiating return-to-home with remaining power or landing the drone safely, prioritizing battery monitoring throughout the flight to prevent critical depletion.
- **Motor or propeller failures**: It demand immediate throttle reduction, stabilizing the drone for a prompt landing in a secure location, with subsequent flights contingent upon thorough damage inspection.
- **Adverse Weather Condition**: Avoid flying in adverse weather conditions by proactively monitoring forecasts. Ensure strict adherence to operational limits to maintain safety
- **Security Threats:** In the face of illegal intrusion or security threats, immediate landing and reporting to local authorities are imperative, ensuring compliance with regulations and airspace restrictions.

Throughout these emergencies, prioritizing safety is paramount, necessitating operator familiarity with drone capabilities, regular pre-flight checks, and proficiency in emergency procedure.

Activities

Activity 1: Multirotor drone flight emergency procedures

Materials Required: Multirotor drones, pre-flight inspection checklists, safety equipment, communication devices, emergency scenario guides.

Procedure:

1. **Introduction and Safety Briefing:** Assemble students and emphasize the importance of safety in drone operations. Conduct a detailed briefing on potential risks and adherence to safety protocols.
2. **Pre-Flight Inspection Practice:** Demonstrate the pre-flight inspection checklist for multirotor drones and allow them to practice under supervision to ensure readiness.
3. **Emergency Scenario Simulation:** Create and simulate scenarios like GPS signal loss, battery failure, and motor malfunctions. Assign roles such as drone operator, safety observer, and communication coordinator, and conduct drills in a controlled environment.

4. **Flight Training and Response Protocols:** Teach them appropriate response actions, such as regaining control, communicating with ground personnel, and executing safe landings. Provide hands-on flight training for practical experience.

Check Your Progress

A. Multiple Choice Question

1. What is the recommended action for a drone experiencing a "flyaway" situation?
a) Increase speed and altitude
b) Switch to manual control and disable autonomous modes
c) Ignore the issue and continue flying
d) Immediately land the drone

2. In the event of a loss of GPS signal, what is a key recommendation for drone operators?
a) Rely solely on GPS for navigation
b) Transition to manual mode and use alternative sensors
c) Activate obstacle avoidance systems
d) Increase altitude for a stable GPS connection

3. How should operators respond to a collision risk during flight?
a) Ignore the risk and continue flying
b) Activate emergency landing procedures
c) Ascend or descend quickly to avoid obstacles
d) Conduct a thorough inspection post-collision for damage

4. What is a crucial step in managing a loss of communication link between the drone and the remote controller?
a) Attempt complex maneuvers to regain link
b) Activate Return-to-Home (RTH) if feasible
c) Fly the drone further to establish a new link
d) Ignore the loss of communication and continue flying

5. During a battery failure, what action should operators take to ensure a safe landing?
a) Maximize battery depletion for extended flight
b) Start return-to-home procedures with remaining power
c) Continue flying until the battery is completely drained
d) Ignore the low battery warning and fly at high speed

6. How should operators respond to a severe motor or propeller failure?
a) Increase throttle to compensate for the failure

b) Land the drone promptly in a safe location
c) Attempt complex maneuvers to test remaining motors
d) Continue flying with reduced stability

7. What is a key recommendation for handling adverse weather conditions during drone flight?
a) Fly at maximum speed to quickly pass through the weather
b) Refrain from flying in unfavorable weather conditions
c) Increase altitude to avoid weather effects
d) Land the drone and wait for weather improvement

8. In the case of an illegal intrusion or security threat, what should drone operators prioritize?
a) Ignore the intrusion and continue the flight
b) Land the drone and report the incident to local authorities
c) Engage in evasive maneuvers to avoid detection
d) Fly the drone to a different location to evade threats

9. What action is recommended when encountering a loss of signal during flight?
a) Land the drone immediately
b) Fly the drone at maximum speed to regain signal
c) Ignore the signal loss and continue flying
d) Activate Return-to-Home (RTH) if available

10. What should operators do after handling an emergency situation to enhance future preparedness?
a) Ignore the incident and proceed with regular flights
b) Document the incident and report it to regulatory bodies
c) Avoid further training on emergency procedures
d) Continue flying without assessing the drone's condition

Module 3	Airspace Planning for Multirotor Drone Flights

Module Overview

Module 3 “Airspace Planning for Multirotor Drone Flights” is designed to equip with the knowledge and skills necessary for effectively planning and executing drone flights within controlled and uncontrolled airspace. This module covers the fundamental principles of drone flying, mission planning, and the operational aspects of executing a successful drone flight, ensuring adherence to safety and regulatory requirements. Session 1, explores the basic principles of drone flying, including an understanding of flight dynamics, controls, and the environmental factors that affect drone performance. This session lays the groundwork for safe and efficient drone operations by introducing key concepts such as lift, thrust, drag, and yaw, and their practical implications in multirotor drone flights.

Session 2 delves into the knowledge required to prepare a comprehensive mission plan for flying a multirotor drone. This includes identifying objectives, selecting the appropriate equipment, understanding the airspace regulations, and preparing for potential challenges. The importance of pre-flight planning and how it contributes to the success and safety of the mission has been elaborated.

Session 3 focuses on the detailed components of a mission plan, such as defining the flight path, setting altitude and speed parameters, adjusting camera settings, and incorporating emergency procedures. This session emphasizes the critical role of careful planning in ensuring the drone’s operations are aligned with the mission’s objectives and safety requirements.

Session 4 covers mission operations, with hands-on knowledge of take-off and landing procedures, real-time monitoring during flight, data collection techniques, post-flight analysis, and data storage. This session ensures that the missions executes effectively, managing all aspects of the flight from start to finish.

Learning Outcomes

After completing this module, you will be able to:

- Demonstrate drone control mechanisms such as throttle, pitch, yaw, and roll to perform precise maneuvers and ensure stable flight.
- Explain the fundamental principles of aerodynamics, including lift, thrust, and balance, to maintain effective control and stability during drone operations.
- Execute emergency procedures for scenarios like signal loss, power failure, and collisions, showcasing readiness to manage unexpected situations safely.
- Identify mission operations strategies, including pre-flight inspections, real-time monitoring, data collection, and secure storage, to ensure efficient and successful drone missions.

Module Structure

Session 1: Fundamental Principles of Drone Flying
Session 2: Mission Planning for Multirotor Drones
Session 3: Drone Flight Mission Plan
Session 4: Mission Operations Overview

Session 1: Fundamental Principles of Drone Flying

Imagine you are flying a drone in a large field. To make it go up, you push the joystick up. The drone will rise into the sky. If you want it to come back down, you pull the joystick down. This phenomenon is known as throttle up and throttle down. To make it fly forward, you tilt the joystick forward (pitch). If you want the drone to spin around in a circle, you can turn the joystick left or right (yaw). To move the drone left and right is done by pushing the button left and right known as roll. It is like playing a video game, but you are controlling a real flying machine.

1. **Mastering Controls:** Drones typically feature four propellers enabling movement in different directions: up, down, forward, backward, left, and right. The remote controller, equipped with joystick or control sticks, dictates the drone's movements when pushed in specific directions.

2. **Lift and Thrust:** Lift is generated by the spinning rotors or propellers, creating an upward force that elevates the drone. Adjusting rotor speed regulates the drone's altitude, determining how high or low it flies.

3. **Balance and Stability:** Drones incorporate sensors to maintain equilibrium and stability during flight, detecting positional changes and making necessary adjustments. Gyroscopes and accelerometers contribute to keeping the drone level and preventing tilting.

4. Directional Movement: Varied rotor speeds enable the drone to move in distinct directions.Increase front rotor speed to move forward. Adjust rotor speeds on one side for left or right turns.

Fundamentals of flight and aerodynamics

Drones, have become incredibly popular for everything from aerial photography to delivering packages. Understanding how drones fly involves some basic principles of flight and aerodynamics.

Basic Forces of Flight

Just like airplanes, drones are affected by four main forces: lift, weight, thrust, and drag **(Figure 3.1)**.

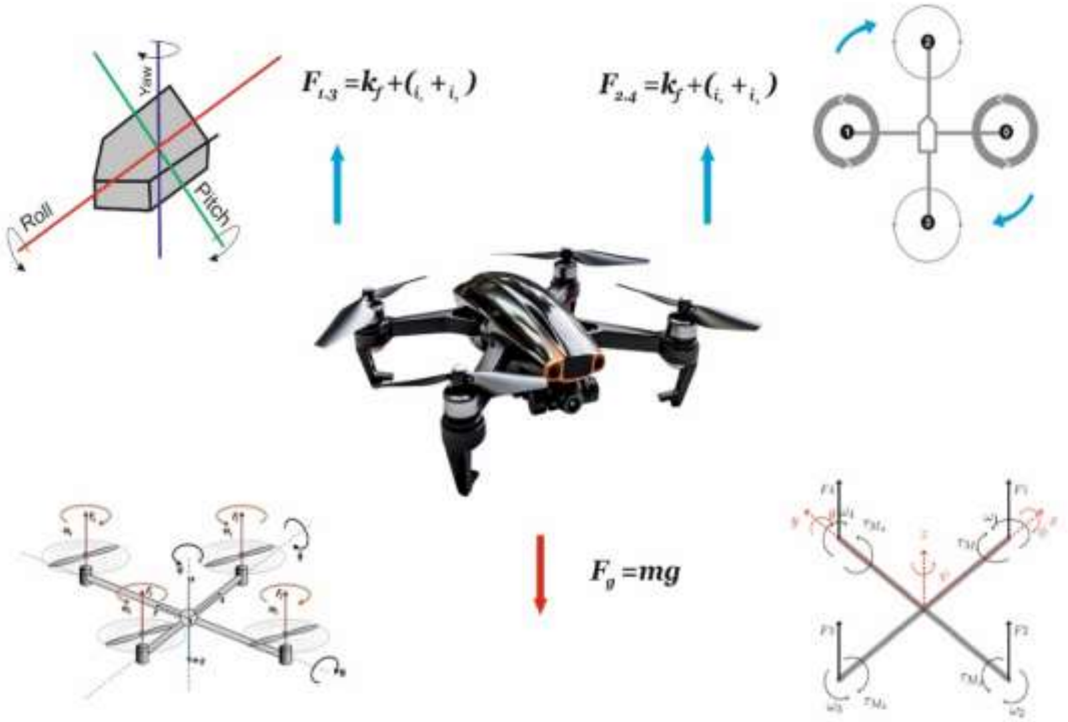

Figure 3.1: Basic forces of flight

Lift: Lift is the force that pushes the drone up into the air. For drones, lift is generated by the spinning propellers. lift is the force generated by the rotors (propellers) that counteracts gravity and keeps the drone in the air. Lift is created when the rotors spin rapidly, creating low pressure above the blades and higher pressure below, causing the drone to rise. The amount of lift can be adjusted by varying the speed of the rotors.

Weight: Weight is the force that pulls the drone down toward the ground. It is caused by gravity.

Thrust: Thrust is the force that moves the drone forward. In drones, thrust is also generated by the propellers, which can tilt in different directions to move the drone.

Drag: Drag is the resistance encountered by the drone as it moves through the air, and it works to slow the drone down. For a drone to hover in place, the lift generated by the propellers must equal the weight of the drone, and the thrust must balance the drag. This balance allows the drone to maintain a stable position in the air.

Throttle: It is the control input that adjusts the speed of the rotors to change the drone's altitude. Increasing the throttle increases rotor speed, generating more lift and causing the drone to ascend. Conversely, decreasing the throttle lowers the rotor speed, reducing lift and making the drone descend. Throttle is key to maintaining stable flight and controlling the drone's vertical movement.

How Drones Generate Lift

Drones typically feature four or more rapidly spinning propellers to generate lift. The propellers are designed like small wings; as they spin, they push air downwards. This downward push creates an upward reaction force, known as lift, which enables the drone to rise off the ground. By adjusting the speed of the propellers, the drone can control the amount of lift generated. Faster spinning propellers produce more lift, causing the drone to rise, while slower spinning propellers generate less lift, making the drone descend.

How Drones Move

Drones achieve movement in all directions by adjusting the speed and direction of their propellers. To move up or down, the drone increases or decreases the speed of all propellers equally, causing it to rise or descend. For forward or backward movement, the drone tilts the propellers to push air in the opposite direction, which propels the drone accordingly. To move left or right, the drone tilts the propellers to one side, enabling sideways movement. Yawing, or rotating left or right, is accomplished by speeding up the propellers on one side while slowing down those on the other, allowing the drone to rotate in place.

Stability and Control

Drones are equipped with sensors and onboard computers that play a crucial role in maintaining stability and responding to control inputs. Gyroscopes and accelerometers are key components in this system; they detect changes in the drone's orientation and movement, helping to keep the drone balanced. By continuously monitoring and adjusting for any deviations, these sensors ensure smooth and controlled flight, enabling the drone to maintain stability and respond effectively to the pilot's commands.

Flight Controllers: The onboard computer, or flight controller, processes data from the sensors and adjusts the propeller speeds to maintain stability and execute the pilot's commands. Pilots use a remote control to send instructions to the drone, and the flight controller interprets these commands, making real-time adjustments to the propellers to ensure the drone remains stable and follows the desired flight path. This seamless integration between the remote control and flight controller allows for precise maneuvering and control of the drone.

Common Drone Maneuvers

Common drone maneuvers refer to the basic movements or actions a drone can perform during flight. These maneuvers allow the operator to control the drone's direction, stability, and positioning. Key maneuvers include:

- **Yaw** – Rotating the drone around its vertical axis, causing it to turn left or right.
- **Pitch** – Tilting the drone forward or backward, allowing it to ascend or descend at an angle.
- **Roll** – Tilting the drone sideways (left or right) along its longitudinal axis to change direction.
- **Hovering** – Maintaining a stable position in the air without moving, typically achieved by balancing lift and throttle.
- **Flight Path Changes** – Moving the drone forward, backward, or sideways, adjusting speed and direction.

Activities

Activity 1: Flight simulation and risk assessment

Materials Required: Simulation software for flight planning, flight planning templates, weather monitoring tools, risk assessment and emergency protocol guides

Procedure:

- Introduce students to the principles of aerodynamics and flight planning, discussing weather, airspace, and obstacle considerations.
- Teach them how to calculate optimal flight parameters (altitude, speed, etc.), and develop flight paths based on drone specifications.
- Use flight simulation software to practice, followed by real-world flight execution, and conclude with a debriefing to evaluate performance and discuss improvements.

Activity 2: Basic maneuver training for multirotor drones in a simulator

Materials Required: Drone flight simulator software, joysticks/controllers, safety equipment, computers with simulation capability

Procedure:

- Begin with a safety briefing, emphasizing the importance of safety protocols even in a simulated environment. Introduce students to the flight simulator interface, explaining the controls and features available for drone operation.
- Demonstrate basic drone maneuvers such as ascending, descending, hovering, yawing, and moving in different directions within the simulator. Guide them through these maneuvers, ensuring they understand the necessary control inputs for each action.
- Gradually introduce more complex maneuvers, like figure-eight patterns and circular flight paths, within the simulator. Encourage them to experiment with these maneuvers in a controlled setting, using the simulator's features to set up different flight challenges and scenarios.

Check Your Progress

A. Multiple Choice Question

1. What is the primary force responsible for the take-off of an aircraft?
a) Weight
b) Lift
c) Yaw
d) Drag

2. During flight, what force opposes thrust and is caused by the resistance of the air through which the aircraft is moving?
a) Weight
b) Lift
c) Thrust
d) Drag

3. Which control surfaces are typically manipulated by pilots to control the roll of an aircraft during turns?
a) Elevators
b) Rudders
c) Ailerons
d) Flaps

4. What is the purpose of a circuit pattern in aviation?
a) To perform aerobatic maneuvers
b) To navigate through traffic on the ground
c) To follow a standard path for take-off and landing
d) To conduct emergency landings

5. What is the phase of flight where the aircraft returns to the ground?
a) Take-off
b) Flight
c) Maneuvers
d) Landing

6. Which force is directly opposed by lift during flight?
a) Thrust
b) Weight
c) Drag
d) Momentum

7. In a turn, what control input is responsible for banking the aircraft to one side?
a) Ailerons
b) Elevators
c) Rudders
d) Flaps

8. What is the key factor in maintaining control during maneuvers like climbs, descents, and rolls?
a) Weight distribution
b) Engine power
c) Control surface manipulation
d) Fuel efficiency

9. Which phase of flight involves a gradual reduction in speed, descent rate management, and alignment with the runway?
a) Take-off
b) Flight
c) Maneuvers
d) Landing

10.What is the purpose of adjusting rotor speeds in drone flight?
a) To control altitude
b) To perform aerobatic stunts
c) To enhance speed
d) To reduce drag

Session 2: Mission Planning for Multirotor Drones

Mission planning for multirotor drones is a critical process that involves preparing a flight to achieve specific goals while ensuring safety, efficiency, and compliance with regulations. Proper planning ensures successful drone operations, reduces the risk of failure, and ensures adherence to legal and safety requirements.

1. **Inspection of Mission**

   The inspection of mission includes the following key points:

   i. **Site Survey**: Identify and survey the designated area for the drone mission to understand its physical characteristics, hazards, obstacles, and key landmarks. Define the geographical boundaries and take note of structures, power lines, or other elements that may affect the flight path.

   ii. **Risk Assessment**: Evaluate potential risks associated with the mission, including environmental factors like weather conditions, and assess the proximity to people, structures, or sensitive areas. Develop strategies to mitigate risks and ensure a safer mission.

   iii. **Equipment Check**: Inspect the drone for any damage, ensure critical components (e.g., propellers, motors, battery) are functioning properly, and verify the remote controller and communication links are reliable. Calibrate sensors and check the functionality of cameras or other payloads.

   iv. **Legal and Regulatory Compliance**: Ensure compliance with local laws, regulations, and airspace restrictions. Verify the need for permits, check for no-fly zones, and follow privacy laws, especially for surveillance or inspection missions. Establish communication with stakeholders and air traffic control as necessary, and develop emergency protocols.

2. **Mission checks**

   It covers a pre-flight checklist, battery management, and controller and communication systems:

   Pre-flight Checklist: Conduct a visual inspection to examine the drone, propellers, and other components for any visible damage or wear. The objective is to verify the optimal condition of all drone components before take-off. Ensure that the drone's firmware and software are up-to-date. Confirm the functionality of safety features, such as return-to-home (RTH), to ensure they operate correctly. Test the motors and propellers for smooth operation and calibrate the drone’s sensors and GPS to ensure accurate navigation.

Battery Management: Before each flight, verify that the battery is fully charged or adequately powered for the planned duration. Ensure the battery is installed securely and correctly in the drone. Check for any signs of damage or degradation to the battery. If using multiple batteries, confirm both individual and combined capacities to ensure redundancy and reliability during the flight.

Controller and Communication: Conduct a thorough inspection of the remote controller and communication systems, ensuring responsiveness of buttons, proper antenna orientation, and stable signal connection. Ensure that the remote controller and communication systems are fully functional for effective drone control by following a thorough inspection protocol. Verify accurate telemetry data display and test the return-to-home function. For aerial photography, check the drone's physical integrity, update firmware, and calibrate sensors before flight.

Systematic pre-flight checks enhance drone safety, reduce in-flight risks, and contribute to the overall success of the mission.

3. Mission Plan

It refers to the detailed strategy for conducting a drone operation, ensuring safe and effective execution. It typically covers the following key aspects:

i. **Flight Path**: The planned route the drone will follow during the mission, often mapped out using GPS waypoints or software. The flight path should avoid obstacles and restricted areas while covering the designated mission area.

ii. **Altitude**: The height at which the drone will fly during the mission. This is determined by factors like the type of operation (e.g., inspection, mapping), safety concerns (e.g., avoiding trees, buildings), and legal regulations (e.g., maximum allowable altitude). Maintaining the correct altitude ensures proper performance of sensors and avoids airspace conflicts.

iii. **Speed**: The speed at which the drone will travel during the mission. This should be set to balance efficiency and safety, depending on the type of data being collected (e.g., slower speeds for detailed aerial imagery) and environmental conditions (e.g., wind speed).

iv. **Camera Settings**: Configuring the drone's camera or other sensors for optimal data capture. This includes adjusting settings like resolution, shutter speed, focus, and exposure based on the mission's purpose (e.g., high-definition video, thermal imaging, or LiDAR scanning).

v. **Emergency Procedures**: Established protocols for dealing with unexpected situations or malfunctions, such as loss of signal, low battery, or sudden weather changes. This includes planned actions like returning to home (RTH), emergency landings, or communication with ground personnel to ensure the drone's safety and avoid accidents.

4. Mission Operations

It involves the actual execution of the drone mission, from takeoff to landing, and include several critical phases to ensure success and data integrity. Here's a breakdown of each step:

i. **Takeoff and Landing**: This is the initial and final phase of the mission where the drone is safely launched and landed. Takeoff must be performed in a controlled environment, ensuring that the drone has a clear path and stable conditions (e.g., no strong winds). Landing should also be done carefully, avoiding obstacles and ensuring the drone comes to a safe, stable stop at the designated area.

ii. **Real-time Monitoring**: During the mission, operators continuously monitor the drone's performance, flight path, and sensor data in real time. This includes checking for issues like battery levels, GPS accuracy, camera settings, and maintaining communication with the drone. Monitoring tools may include a remote controller display or a mission planning app that shows live data, such as altitude, speed, and location.

iii. **Data Collection**: This involves capturing the primary data for the mission, whether it is images, videos, LiDAR scans, or thermal readings. Data collection settings must be optimized for the mission's objectives (e.g., capturing high-resolution images for surveying or inspecting structures). The data must be captured accurately throughout the mission according to the pre-set flight plan.

iv. **Post-flight Analysis**: After landing, the collected data is processed and analyzed to extract useful insights. This can include stitching images for mapping, reviewing video footage for inspection purposes, or analyzing sensor data. Post-flight analysis is essential for assessing the quality and completeness of the mission's objectives and ensuring that all required data has been captured.

v. **Data Storage**: All collected data needs to be securely stored for later use. This can be done on local storage devices (e.g., SD cards or onboard memory) and/or uploaded to cloud storage or a centralized database. Data integrity and redundancy are important for preventing loss of information, especially for critical missions such as inspections or surveys.

Activities

Activity 1 : Emergency procedures training for drone operations

Materials Required: Drone, remote controller, fully charged battery, training area, safety gear, mission planning app, backup battery

Procedure:

- Simulate communication loss between the drone and remote controller, practicing emergency protocols for regaining control and handling flyaways.
- Conduct battery failure scenarios, instructing students on safe descent procedures and proper management of low battery situations.
- Test the Return-to-Home (RTH) function in various conditions, observing the drone's response to GPS loss, signal interruptions, and other emergencies to verify its reliability.

Check Your Progress

A. Multiple Choice Questions

1. What is the primary purpose of conducting a site survey before a drone mission?
a) To check the drone's battery levels
b) To identify hazards, obstacles, and key landmarks that may affect the flight path
c) To test the drone's communication system
d) To determine the drone's altitude and speed

2. Which of the following is a critical component of risk assessment during mission planning?
a) Assessing the weather, proximity to people, and sensitive areas
b) Ensuring the drone's firmware is up-to-date
c) Calibrating the drone's sensors
d) Verifying the drone's camera settings

3. What should be checked during the equipment inspection for a drone mission?
a) Only the battery
b) The remote controller, propellers, sensors, and cameras
c) Just the flight path
d) Only the flight path software

4. In a mission plan, why is the flight path critical?
a) To ensure proper camera settings
b) To monitor the drone's real-time data
c) To avoid obstacles and restricted areas while covering the mission area
d) To decide the drone's altitude

5. What is the purpose of testing the Return-to-Home (RTH) function during mission checks?
a) To test the drone’s camera settings
b) To ensure the drone returns to the home location during signal loss or low battery
c) To check the battery management system
d) To calibrate the drone’s sensors

6. What should be done during the post-flight analysis phase?
a) Monitor the drone’s real-time data
b) Inspect the drone’s physical condition
c) Ensure the battery is charged
d) Process and analyze the collected data to extract useful insights

7. How should collected drone data be stored after the mission?
a) Only on the remote controller
b) On local storage devices (e.g., SD cards) and/or uploaded to cloud storage
c) On a laptop
d) On the drone's camera only

Session 3: Drone Flight Mission Plan

A mission plan serves as a pivotal framework for the successful execution of drone operations, encompassing critical components such as flight path, altitude, speed, camera settings, and emergency procedures. Below is an overview of the key components involved in planning a drone mission:

i. **Mission Objectives:**
- **Define the Purpose:** Clearly outline the goal of the flight (e.g., aerial photography, surveying, mapping, inspection, etc.).
- **Data Collection Requirements:** Specify the type of data to be collected (e.g., images, videos, LiDAR scans) and any specific requirements (e.g., resolution, frequency).

ii. **Flight Path:**
- **Route Planning:** Map out the drone’s flight path using GPS waypoints or mission planning software, ensuring that it avoids obstacles and restricted areas.

- **Area Coverage:** Define the area to be surveyed or covered, ensuring adequate overlap for image stitching if necessary.
- **Waypoint Accuracy:** Ensure that GPS waypoints are precisely set for accurate navigation.

iii. Altitude and Speed:

- **Altitude:** Determine the optimal flying height based on mission type, legal restrictions, and safety considerations (e.g., for inspections, a lower altitude might be required).
- **Speed:** Set an appropriate speed for the drone based on mission objectives (e.g., slower speeds for detailed imagery or faster for efficiency).

iv. Weather Assessment:

- **Check Conditions:** Review weather forecasts for wind speed, temperature, precipitation, and visibility. Avoid flying in adverse weather conditions like strong winds or rain.
- **Real-time Monitoring:** Continuously monitor weather during the mission to detect any changes that could affect flight safety.

v. Airspace and Regulatory Compliance:

- **Airspace Restrictions:** Identify and comply with any no-fly zones or restricted airspace in the mission area (e.g., airports, military zones).
- **Permits and Permissions:** Ensure any required permits are obtained, especially for flights in controlled airspace or over private property.
- **Altitude Limits:** Verify that the planned altitude complies with local aviation regulations and guidelines.

vi. Equipment and Sensor Configuration:

- **Drone Setup:** Inspect the drone for damage or wear, and verify that components like motors, propellers, and GPS are functional.
- **Sensor Settings:** Calibrate cameras, thermal sensors, or other payloads to ensure optimal data capture for the mission.
- **Battery Check:** Ensure batteries are fully charged and have enough capacity for the entire mission.

vii. Emergency Procedures:

- **Return-to-Home (RTH):** Test the RTH function to ensure the drone can return safely in case of communication failure or low battery.
- **Battery Failure Plan:** Set emergency landing zones and protocols in case the battery level becomes critically low.
- **Lost Communication Protocol:** Define steps to take if the drone loses connection with the remote controller (e.g., RTH or manual intervention).
- **Flyaway and Collision Handling:** Prepare procedures for handling flyaways or unexpected collisions.

viii. Post-flight Operations:

- **Data Storage:** Ensure all collected data is properly stored on the drone's SD card or transferred to a secure system.
- **Data Backup:** Back up important data to prevent loss due to technical failures.
- **Post-flight Analysis:** Review the mission results and verify that the objectives were met. Assess data quality for further processing (e.g., image stitching or 3D modelling).

ix. Safety and Communication:

- **Safety Briefing:** Ensure all personnel involved in the mission are familiar with the flight plan and emergency procedures.
- **Real-time Monitoring:** Have a ground operator monitor the flight, track the drone's position, and maintain communication with the pilot.
- **Stakeholder Communication:** Notify relevant parties (e.g., property owners, local authorities) about the mission and its potential impact.

x. Contingency Planning:

- **Alternative Plans:** Prepare for unexpected changes in weather or technical issues, and establish a backup plan for the mission if required.

Activities

Activity 1: Group discussion on drone flight planning and maneuver practice

Materials Required: Notebooks and pens,

Procedure:

- Engage in a group discussion to review the fundamentals of aerodynamics, focusing on concepts like lift, thrust, and stability.
- Develop a discussion on flight plan incorporating route selection, altitude, and speed adjustments based on the aerodynamic principles discussed.

Check Your Progress

A. Multiple Choice Question

1. Which of the following best describes the purpose of defining mission objectives in a drone operation?

a) To create a flight path with GPS waypoints

b) To set the return-to-home (RTH) function
c) To clearly outline the goal of the flight and specify data collection requirements
d) To monitor weather conditions in real-time

2. What is the primary reason for ensuring GPS waypoints are precisely set during route planning?
a) To comply with local airspace regulations
b) To enhance communication with stakeholders
c) To ensure accurate navigation and avoid restricted areas
d) To calibrate the drone's sensors for data collection

3. Why is it crucial to assess weather conditions before and during a drone mission?
a) To determine the optimal camera settings
b) To prevent unexpected altitude adjustments
c) To ensure the mission stays within the planned route
d) To avoid flying in adverse weather that could impact flight safety

4. Which of the following is an example of a contingency plan in drone mission operations?
A) Mapping the drone's flight path using mission planning software
B) Preparing alternative plans for unexpected weather changes or technical issues
C) Setting camera resolution for optimal data collection
D) Monitoring the drone's battery level before flight

5. What action should be taken to comply with airspace and regulatory requirements during a drone mission?
a) Use higher altitudes for better data collection
b) Monitor weather conditions only at the start of the flight
c) Identify no-fly zones and obtain necessary permits
d) Increase the drone's speed for efficient coverage

Session 4: Mission Operations Overview

Mission operations within drone management involve a coordinated sequence of actions to facilitate a seamless and successful workflow. The following outlines key aspects of mission operations, covering take-off and landing, real-time monitoring, data collection, post-flight analysis, and data storage:

Drone mission operations encompass several critical stages, each essential for a successful and efficient flight. The process begins with takeoff and landing, where precise control ensures safe departure and return of the drone. During the flight, real-time monitoring is conducted to track the drone's status and surroundings, allowing for immediate adjustments if necessary.

Data collection is another vital aspect, as the drone gathers information through its sensors and cameras. Following the flight, post-flight analysis involves reviewing the collected data to extract valuable insights and assess the mission's success. Data storage ensures that all information is securely archived for future reference and analysis.

Each of these stages plays a crucial role in the overall operation and effectiveness of drone missions:

1. **Pre-landing Operations**
   - Ensure the landing area is clear of obstacles and safe for descent.
   - Confirm that the drone’s battery level is sufficient for a safe landing.
   - Monitor any changes in weather conditions that could affect landing safety.

2. **Post-landing Inspections**
   - Check the drone for any visible damage to its frame, propellers, and motors.
   - Inspect sensors and cameras for cleanliness and possible damage.
   - Ensure landing gear is intact and functioning properly.

3. **Post-flight Checks**
   - Review flight logs and data to verify successful mission completion.
   - Assess the battery status and recharge or replace if needed.
   - Transfer collected data to a secure storage system for analysis.

4. **Areas of Focus**
   - Maintain awareness of surroundings and potential hazards.
   - Verify that all required data has been collected and meets the expected quality standards.
   - Ensure the mission adheres to local regulations and airspace restrictions.

5. **Manual Flight Profiles**
   - Develop and practice specific manual flight manoeuvres such as hovering, lateral movements, and precision landing.
   - Use manual flight when automated functions are insufficient for the task or during complex operations.
   - Include manual override capabilities for handling unexpected situations or emergencies.

6. **Real-Time Monitoring**
   Once airborne, real-time monitoring becomes essential. This involves continuously tracking the drone's status, including its position, altitude, battery level, and overall system health. Real-time monitoring allows operators to detect and respond to any potential issues immediately. It also includes observing the drone's surroundings to avoid obstacles and comply with airspace regulations. Advanced drones may use GPS, telemetry data, and live video feeds to provide comprehensive situational awareness.

7. **Data Collection**
   During the flight, the drone's sensors and cameras are actively engaged in data collection. This can include high-resolution images, video footage, thermal imaging, LiDAR data, and more, depending on the mission's objectives. Accurate and high-quality data are crucial because they determine the mission's success. Effective data collection requires well-calibrated equipment and precise flight paths to cover the target area thoroughly.

8. **Data Storage**
   After the mission, all collected data must be securely stored for future reference and analysis. This involves transferring the data from the drone to secure storage systems, which may include cloud services or local servers. Proper data storage ensures that information is readily accessible for post-flight analysis, which can provide valuable insights and support decision-making processes. It also involves implementing security measures to protect the data from unauthorized access or loss.

Each of these stages take-off and landing, real-time monitoring, data collection, and data storage plays a crucial role in the overall operation and effectiveness of drone missions. Proper execution of each stage ensures that the mission is conducted efficiently, yielding valuable data and insights for various applications.

Activities

Activity 1: Pre- and Post-Landing Drone Check Mastery

Materials Required: Drones for practice, Checklists for pre- and post-landing checks, Safety equipment, Notepads and pens.

Procedure:

- Highlight the importance of pre- and post-landing checks for safe drone operations.
- Demonstrate key pre-landing procedures, such as assessing battery levels and signal strength.
- Divide students into groups to practice pre-landing checks using the provided checklists.
- Transition to a guided practice session focusing on post-landing checks, teaching them how to inspect drones for damage.
- Conclude with a review session to discuss any challenges faced, answer questions, and provide a summary of the checks.

Check Your Progress

A. Multiple Choice Question

1. Why is real-time monitoring essential during a drone mission?
a) To track the drone's position and altitude for compliance with airspace regulations
b) To ensure the drone's battery is charged before flight
c) To review post-flight logs for data analysis
d) To increase the drone's speed during flight

2. What should be checked during post-landing inspections?
a) Only the battery status
b) The drone's frame, propellers, motors, sensors, and cameras for any visible damage
c) The data storage system for adequate capacity
d) The quality of the collected data only

3. Which of the following is crucial for successful data collection during a drone mission?
a) Ensuring the drone is fully charged before takeoff
b) Calibrating sensors and cameras to capture high-quality images, videos, or other required data
c) Monitoring weather conditions throughout the flight
d) Regularly updating the drone's software during the flight

4. Why is it important to verify that the mission adheres to local regulations and airspace restrictions?
a) To ensure the drone can fly at its maximum speed
b) To prevent damage to the drone's sensors
c) To ensure legal compliance and avoid potential penalties or conflicts with air traffic
d) To save on battery consumption during the flight

5. Which of the following is an example of manual flight profiles during a drone mission?
a) Relying solely on automated flight modes
b) Performing specific manual maneuvers such as precision landing when automated functions are insufficient
c) Flying at maximum altitude regardless of conditions
d) Using real-time monitoring data only for troubleshooting

6. What is the primary purpose of transferring collected data to a secure storage system after a drone mission?

a) To reduce the flight time for future missions
b) To ensure that the data is available for post-flight analysis and decision-making
c) To charge the drone's battery for future flights
d) To make the drone available for another mission immediately

7. What should be done before the drone lands during pre-landing operations?
a) Make sure the drone's battery is full and check for surrounding weather conditions
b) Assess the battery level, monitor weather conditions, and ensure the landing area is clear of obstacles
c) Disable real-time monitoring
d) Only check the drone's camera settings and sensors for issues

Module 4	Operating a Multirotor Drone

Module Overview

Module 4 on "Operating a Multirotor Drone" is focused on developing the practical skills and expertise required to operate a multirotor drone effectively and safely. This module provides a structured approach to building proficiency in drone flying, starting from foundational skills to achieving a level of competency that ensures confident and controlled operations.

Session 1, introduces the procedures necessary for developing expertise in multirotor drone flying. This session covers the progressive stages of skill acquisition, including basic maneuvers, flight pattern practice, and the refinement of control techniques. Students will explore the importance of consistent practice, familiarization with the drone's controls, and understanding how to adapt to different flight conditions. The session aims to guide learners through the process of becoming proficient drone operators by mastering the fundamental aspects of drone flying.

Session 2 focuses on achieving a basic operating capability for flying a multirotor drone. This session provides hands-on training in essential flight operations, including take-off, hovering, directional control, and landing. Students will gain practical experience in executing standard flight tasks and managing the drone under various conditions. The session emphasizes the importance of building a strong foundation in basic operations before progressing to more advanced flying techniques.

Learning Outcomes

After completing this module, you will be able to:

- Demonstrate proficiency in essential drone maneuvers.
- Explain basic flight patterns such as figure-eight, squares, and circles with accuracy and control.
- Describe advanced techniques and safety protocols for handling various flight scenarios.

Module Structure

Session 1: Multirotor Drone Flying Expertise

Session 2: Essential Skills for Multirotor Drone Flight

Session 1: Multirotor Drone Flying Expertise

Operating a multirotor drone involves expertise a range of essential flight maneuvers and understanding key control principles to ensure safe and effective operation. This section covers fundamental skills such as takeoff and landing, hovering, banked turns, and yaw control, providing a comprehensive guide for pilots to develop proficiency. By focusing on these core techniques, drone operators can build a strong foundation for more advanced flying tasks, enhance their control capabilities, and ensure they can handle various flight scenarios effectively.

1. Basic flight maneuvers (takeoff and landing, hovering, banked turns, yaw control)

Mastering basic flight maneuvers is essential for proficiency in multirotor drone flying. Key skills include takeoff, landing, hovering, banked turns, and yaw control. Takeoff involves pre-flight checks, gradually increasing throttle, and maintaining a steady ascent to a safe altitude. Landing requires gently decreasing throttle and aiming for a specific spot, ensuring the area is clear of obstacles. Practicing these maneuvers in different conditions builds confidence, adaptability, and control for better flight performance.

i. **Hovering:** Hovering involves keeping the drone stationary in mid-air. For basic hovering, position the drone at a desired altitude and use minimal stick movements to maintain its position, focusing on stability and resisting drift caused by wind or slight control imbalances. Precision hovering requires practicing over a fixed point, such as a marker on the ground, which is crucial for tasks that demand the drone remain in one place, such as capturing detailed photographs or conducting inspections.

ii. **Banked Turns:**

- Gently push the right stick (mode 2 controllers) left or right to tilt the drone.
- Apply slight throttle adjustments to keep the drone at a consistent altitude during the turn.
- Use the left stick to manage yaw, balancing the drone's tilt and yaw for a smooth, coordinated turn.
- Gradually center the sticks to level the drone, transitioning smoothly back to straight flight.
- Perform banked turns at various speeds and angles to improve control and fluidity.

iii. **Yaw Control:**

- Use the left stick (mode 2 controllers) to rotate the drone left and right.
- Focus on smooth, controlled rotations without causing drift.

- Combine yaw with other controls like throttle and pitch for complex maneuvers.
- Perform pirouettes or coordinated turns to enhance control.
- Use yaw control to navigate tight spaces and adjust the drone's orientation quickly.
- Consistent practice of yaw control alongside takeoff, landing, hovering, and banked turns builds a strong foundation.
- Mastery of yaw control ensures safe, efficient, and confident operation, preparing you for more complex drone tasks and missions.

2. **Basic flight patterns**

Mastering basic flight patterns is essential for developing precise control and confidence in flying a multirotor drone. These patterns include flying in a figure of 8 at different elevations, square patterns, and circle patterns. Each pattern helps improve various aspects of flight control, including orientation, stability, and maneuverability.

i. **Figure of 8 Pattern:** The figure of 8 pattern helps improve coordination and control while changing directions. To practice the figure-eight maneuver, start by hovering at a stable altitude in an open area free of obstacles. Begin by flying in a straight line, then smoothly turn the drone to form the first loop of the eight. After crossing the starting line, complete the second loop. Practice this pattern at various elevations to enhance both vertical and horizontal control. Focus on achieving smooth transitions between the loops while maintaining a consistent altitude throughout the maneuver.

ii. **Square Pattern:**

- Flying in a square pattern aids in precision with directional changes and maintaining consistent flight paths.
- Start by hovering at a stable altitude and identifying **four** (square points) to form a square either in the air or on the ground.
- Begin by flying straight to the first point, then make a 90-degree turn to proceed to the second point.
- Continue to the third and fourth points to complete the square.
- Practice this pattern at various elevations, ensuring to maintain a consistent altitude throughout each leg of the square.
- Focus on making sharp, controlled 90-degree turns and maintaining straight flight paths between the points.

iii. **Circle Pattern:** Flying in a circle pattern helps with smooth, continuous directional control and maintaining a stable altitude. To execute a circular flight maneuver, start by hovering at a stable altitude and identifying a central point around which to fly the circle. Begin flying in a smooth, circular path around this central point, ensuring that the drone's orientation remains consistent, either facing inward or outward from the circle. Practice flying circles at various elevations to enhance vertical control, and focus on maintaining a consistent distance from the central point while keeping a stable altitude throughout the maneuver.

iv. **Combining Patterns:** Once comfortable with individual patterns, combine them to further enhances one's control and adaptability.

v. **Complex Patterns**: Combine the figure of 8, square, and circle patterns into a single flight routine. For example, fly a figure of 8, transition into a square pattern, and finish with a circle.

vi. **Transitions**: Practice smooth transitions between different patterns, maintaining control and stability.

vii. **S-Curve Pattern:** The S-curve pattern involves flying a sequence of connected curves resembling the letter "S," transitioning smoothly between left and right turns. This pattern is employed to refine skills in smooth and coordinated directional changes and precise bank angle control.

viii. **Oval Pattern:** The oval flight pattern requires guiding the aircraft in the shape of an oval or elongated circle, maintaining coordinated turns. Oval patterns are beneficial for practicing turns in both directions, keeping a constant bank angle, and adapting to changes in airspeed.

ix. **Cloverleaf Pattern:** The cloverleaf pattern **(Figure 4.1)** incorporates four 90-degree turns arranged in the shape of a cloverleaf, executing a series of connected right-angle turns.

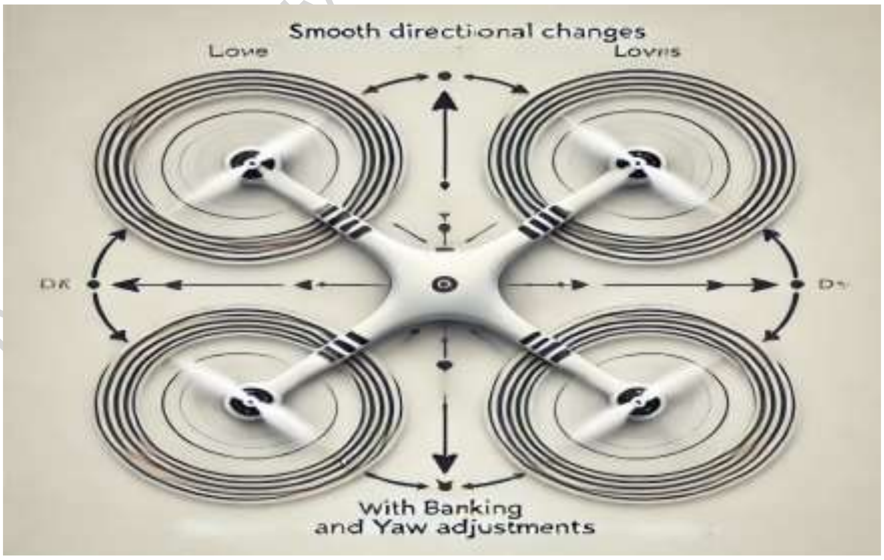

Figure 4.1: Cloverleaf pattern

This pattern is useful for refining skills in precise turning, altitude control, and coordination during pattern flying.

These fundamental flight patterns serve as essential training elements, allowing pilots to develop and enhance their core flying abilities. They are integral to flight training programs, ensuring that pilots can proficiently manage various maneuvers and navigate effectively in diverse flight scenarios.

3. **Advanced maneuvers**

Advanced manoeuvres involve flips, rolls, and auto stabilization for controlled flight. They are described as follows:

i. **Flips and Rolls:**

- **Flips:** A flip is an aerial maneuver characterized by a complete 360-degree rotation along the aircraft's longitudinal axis (nose to tail). Typically associated with aerobatic flying, executing flips demands precise control inputs for a safe performance.
- **Rolls:** Rolls involve a 360-degree rotation along the aircraft's lateral axis (wingtip to wingtip). Various types of rolls exist, such as aileron rolls (controlled by ailerons) and barrel rolls (a combination of roll and pitch). Achieving rolls requires skillful coordination of aileron inputs.
- **Execution:** Pilots initiate flips and rolls by applying specific control inputs. Flips require a combination of pitch and roll inputs, while rolls primarily involve aileron input. Successful execution requires careful consideration of altitude, airspeed, and G-forces to maintain the aircraft's structural integrity.

ii. **Auto-Stabilization Mode:** Auto-stabilization mode is a feature that helps maintain an aircraft's stability by using sensors and gyroscopes to monitor and correct its position. It assists pilots in challenging conditions, counteracting disturbances like turbulence and wind gusts. While it enhances safety, pilots must avoid overreliance on automation and maintain manual control skills. Proper training ensures effective use of auto-stabilization and aerobatic maneuvers like flips and rolls, contributing to overall flight safety and control.

4. **Autonomous flying**

Autonomous flying pertains to the capability of an aircraft to operate and navigate through airspace without direct human control. This functionality relies on cutting-edge technologies, including artificial intelligence (AI), sensors, and intricate algorithms, to make decisions and manage the aircraft's movements. The following are key facets of autonomous flying:

Autonomous Systems:

Autonomous systems operate independently, performing tasks without human intervention or control. They are as follows:

- **Artificial Intelligence (AI)**: Autonomous flying systems commonly integrate AI to process large volumes of real-time data. Machine learning algorithms enable the aircraft to learn and adapt based on experience, enhancing decision-making capabilities over time.

- **Sensor Technologies**: Diverse sensors, such as GPS, inertial navigation systems, Lidar, radar, and cameras, supply crucial data for autonomous flight. These sensors assist the aircraft in perceiving its surroundings and making informed decisions.

Autonomous Functions

It refers to tasks or operations performed by a system without human intervention, relying on sensors, algorithms, and decision-making processes. In drones, autonomous functions can include navigation, obstacle avoidance, flight path planning, and mission execution, all carried out independently based on pre-set instructions or real-time environmental data. These are explained as follows:

- **Takeoff and Landing:** Autonomous systems can adeptly handle the takeoff and landing phases of flight. This encompasses guiding the aircraft along the runway, accommodating varying wind conditions, and executing a safe and precise landing.

- **Navigation:** Autonomous flying systems can plan and execute flight routes, adeptly avoiding obstacles and adjusting to changes in weather conditions. GPS and other sensors contribute to maintaining precise position information.

- **Collision Avoidance:** Advanced algorithms empower autonomous aircraft to identify and evade obstacles in their flight path. This capability is vital for secure navigation, particularly in dynamic and crowded environments.

Applications of Autonomous Flying

- **Delivery Services:** The exploration of autonomous flying for applications like package delivery involves drones equipped with autonomous capabilities to efficiently transport goods between locations.

- **Surveillance and Monitoring:** Autonomous aircraft find applications in surveillance, monitoring, and data collection across various industries, including agriculture, environmental monitoring, and security.

- **Urban Air Mobility (UAM):** Urban Air Mobility envisions the use of autonomous flying vehicles for short-distance urban transportation, potentially mitigating traffic congestion and providing rapid transit within cities.

Regulatory Considerations

The development and integration of autonomous flying systems are subject to stringent regulatory oversight. Aviation authorities establish guidelines and standards to ensure safety and compliance with existing airspace regulations.

- **Challenges and Considerations**
  Ensuring the safety of autonomous flying remains a top priority. Implementing redundant systems, fail-safes, and rigorous testing is crucial to mitigate potential risks.

- **Regulatory Framework:**
  Regulatory frameworks evolve to address the unique challenges posed by autonomous flying. Authorities need to establish rules governing certification, operation, and integration into existing airspace.

Autonomous flying signifies a transformative leap in aviation, holding the potential to revolutionize diverse industries and reshape approaches to transportation and logistics. Ongoing research and development continue to refine autonomous flying technologies and address associated challenges.

5. Night flying

Flying drones at night presents distinct challenges compared to daytime operations, necessitating careful consideration of visibility, regulatory compliance, and safety measures. Here are essential points to grasp about night drone flying:

i. **Visibility Challenges:**

- Reduced natural light makes it difficult to see obstacles and surroundings.
- Harder to detect trees, power lines, and structures at night, complicating navigation.
- Drones for night flying are equipped with lights to enhance visibility and prevent collisions.
- Proper lighting for takeoff and landing zones is essential for safe operations.
- Additional lighting may be needed to ensure sufficient visibility during operations.

ii. **Regulatory Compliance:** Aviation authorities (in different countries) impose specific regulations governing nighttime drone operations, which may include obtaining special permissions or certifications. Compliance with these regulations often involves adhering to specific lighting requirements, which stipulate the type and intensity of lights necessary for anti-collision purposes to ensure safety during night flights.

iii. **Technology and Tools:** Drones designed for night use often feature specialized cameras with low-light or infrared capabilities to enhance visibility in low-light conditions. Additionally, reliable GPS and positioning systems are crucial for nighttime operations, ensuring accurate navigation and maintaining situational awareness.

iv. **Safety Measures:** Thorough pre-flight procedures are essential, including inspections of lights, verification of drone system functionality, and assessing battery status. Operators must maintain an unobstructed line of sight with the drone, relying on instrumentation and technology such as telemetry data and GPS for navigation. A comprehensive risk evaluation is crucial, taking into account factors like weather conditions, visibility constraints, and potential obstacles associated with night flying.

v. **Training and Certification:** Drone operators interested in night flying should undergo specialized training to address the unique challenges and skills required for safe nighttime operations. Regulatory compliance training is also crucial, as understanding and adhering to regulations specific to nighttime drone flights is often mandated, with some authorities requiring additional certifications. Nighttime drone flying is valuable for applications such as surveillance, search and rescue, and inspections, but successful operations demand meticulous planning, strict adherence to regulations, and the use of appropriate technology to ensure safety and compliance with aviation standards.

Activities

Activity 1: Poster presentation on flight patterns using multirotor drones

Materials Required: Poster boards, markers/pens, flyer or summary sheet, brief handout summarizing key points on drone flight patterns.

Procedure:

- Students research different flight patterns, focusing on how they are executed and their real-world uses.
- Create visually engaging posters with diagrams and concise descriptions of each pattern.
- Set up the posters in a designated area for easy access and viewing.
- Presenters explain each pattern's principles and applications to the audience.

Activity 2: Drone flight coordination and collision avoidance

Materials Required: Multiple drones, remote controllers, flight area, communication devices, markers or visual aids, flight logs or checklists, safety gear

Procedure:

- Emphasise the importance of coordination and maintaining safe distances between drones.
- Go over the controls, features, and functions of each drone and remote controller.
- Show the principles of coordination and spacing between drones during flight.
- Divide students into teams, each with multiple drones and controllers.
- Start with simple flight exercises to build foundational skills.
- Progress to more complex maneuvers, focusing on precise control and effective communication.

Check Your Progress

A. Multiple Choice Question

1. What is the primary control surface used for banking in fixed-wing aircraft during a turn?
a) Elevator
b) Rudder
c) Ailerons
d) Flaps

2. Which control input is crucial for preventing adverse yaw during a turn?
a) Elevator
b) Rudder
c) Ailerons
d) Trim

3. In helicopters, what control is primarily responsible for controlling altitude during hovering?
a) Aileron
b) Collective
c) Rudder
d) Cyclic

4. What is the purpose of the flare maneuver during the landing phase?
a) Increase descent rate
b) Soften the landing impact
c) Initiate a climb
d) Level the wings

5. Yawing in an aircraft involves changes in:
a) Pitch
b) Roll

c) Heading
d) Altitude

6. Which rotor control is responsible for adjusting the pitch of individual rotor blades in a helicopter during hovering?
a) Collective
b) Rudder
c) Cyclic
d) Tail rotor

7. During takeoff, what is the initial phase where the aircraft accelerates down the runway before becoming airborne?
a) Approach
b) Climb
c) Rotation
d) Flare

8. What does the figure of 8 flight pattern involve?
a) Flying in a straight line
b) Flying in a circular path
c) Flying in the shape of the numeral "8"
d) Flying in a zigzag pattern

9. In a square flight pattern, how many right-angle turns are typically included?
a) Two
b) Three
c) Four
d) Five

10. Which flight pattern is characterized by flying in the shape of an oval or elongated circle?
a) Square pattern
b) Circle pattern
c) Figure of 8
d) Oval pattern

Session 2: Essential Skills for Multirotor Drone Flight

Developing basic operating capabilities is essential for safely and effectively flying a multirotor drone. These capabilities include understanding the drone's controls, mastering basic flight maneuvers, executing flight patterns, and ensuring proper safety protocols.

i. **Understanding Drone Controls**

To effectively operate a drone, it is essential to first understand its controls. The basic steps to mastering drone controls are:

- **Controller Layout**: Familiarize with the layout of the remote controller, including the functions of each stick and button. Most controllers have two joysticks. The left stick typically controls throttle (up/down) and yaw (rotation), while the right stick controls pitch (forward/backward) and roll (left/right).

- **Pre-Flight Checks**: Perform pre-flight checks to ensure the drone is in optimal condition. This includes checking the battery level, inspecting the propellers, ensuring the firmware is up-to-date, and confirming GPS connectivity.

ii. **The steps for flying a multirotor drone:**

- **Select a Drone:** Choose based on your needs (purpose, size, flight time, range, and features like GPS or obstacle avoidance).

- **Demo Flight:**
  - Perform pre-flight checks (battery, propellers, firmware).
  - Set up in an open area with good weather.
  - Calibrate the drone if needed, and ensure safety.

- **Take-Off & Flight:**
  - Power on the drone and controller.
  - Gradually increase throttle to lift off.
  - Use the controller to move the drone (yaw, pitch, roll).
  - Monitor battery, signal strength, and stability during flight.

- **In-Flight Checks:** Regularly check battery, signal, stability, and GPS. Adjust as needed.

- **Ensuring Proper Safety Protocols**
  - Verify drone components, battery, and environment for safety.
  - Know how to land or return the drone in case of malfunction.
  - Familiarize with local drone laws and airspace rules.
  - Monitor weather, obstacles, and people to ensure safety.
  - Understand controls, practice maneuvers, and execute safe flight patterns.

iii. **Approaching and Executing a Safe Landing with a Drone**

Approaching and executing a safe landing with a drone requires a combination of careful planning, precise control, and situational awareness. Here are the steps to ensure a safe and controlled landing:

- Select a flat area free of obstacles and check weather conditions.
- Gradually lower altitude, making small adjustments to keep the drone stable and level.
- Hover 1-2 meters above the landing spot to ensure stability and alignment.
- Reduce throttle slowly to avoid a hard landing, and power down the motors once the drone touches the ground.
- Turn off the drone and controller, inspect for damage, and secure the area.

Activities

Activity 1: Practical Drone Operating Skills Development

Material Required: Multirotor drone, remote controllers, pre-flight checklist, suitable open area for practice (free from obstacles), safety gear, smartphone or tablet for firmware updates and GPS connectivity check, flight logbook for tracking progress

Procedure:

- **Familiarize with Remote Controller**: Understand the layout and functions of each stick and button on the remote controller.
- **Pre-flight Checks**: Perform essential checks, including verifying battery levels, inspecting propellers, updating firmware, and ensuring GPS connectivity.
- **Practice Takeoff and Landing**: Start with smooth takeoff techniques, gradually increasing throttle for stable lift-off, and practice landing with controlled descent and throttle adjustments.
- **Hovering Practice**: Focus on maintaining a steady altitude while keeping the drone stationary to master hovering control.
- **Banked Turns and Yaw Control**: Practice performing smooth banked turns and yaw adjustments to enhance the drone's directional agility.
- **Flight Pattern Practice**: Execute basic flight patterns like figure-eight, square, and circular routes to develop control and maneuverability.
- **Safety Protocols**: Use a pre-flight checklist, understand emergency procedures, and adhere to local regulations for safety.

- **Landing Practice**: Choose a clear, flat area for landing, considering wind conditions, and perform gradual descents to avoid hard landings.
- **Regular Practice**: Continuously practice these maneuvers while following safety measures to build proficiency and ensure safe, efficient drone operations.

Activity 2: Demonstrate thrust vectoring to control both the yaw (rotation around the vertical axis) and the pitch (tilting forward or backward) movements in the field.

Materials Needed: Multirotor drone equipped with thrust vectoring capability, open field or outdoor area for flight demonstration, safety gear including helmets and goggles, remote controller for the drone

Procedure:

- **Pre-flight Preparation:**

  a) Choose a suitable outdoor location away from obstacles and people, ensuring safety during the demonstration.
  b) Inspect the drone and ensure it is in proper working condition, with fully charged batteries and securely attached propellers.
  c) Brief students on safety protocols, including maintaining a safe distance from the drone during flight.

- **Explanation of Thrust Vectoring:**

  a) Begin by providing a brief explanation of thrust vectoring, highlighting its role in controlling both yaw and pitch movements.
  b) Describe how adjusting the direction of thrust from the drone's propellers can influence its orientation and movement in the air.
  c) Emphasis the significance of thrust vectoring for maneuverability and agility in various flight scenarios.

- **Demonstration of Yaw Control:**

  a) Take off the drone and hover it at a low altitude to demonstrate stable flight.
  b) Use the remote controller to initiate yaw movements by adjusting the thrust vector of the propellers.
  c) Rotate the drone clockwise and counterclockwise to showcase how thrust vectoring controls its yaw orientation.
  d) Explain the correlation between the direction of thrust and the resulting yaw movement.

- **Demonstration of Pitch Control:**

  a) After demonstrating yaw control, proceed to showcase pitch movements using thrust vectoring.
  b) Fly the drone forward and backward to illustrate pitch tilt in the respective directions.
  c) Manipulate the thrust vector to adjust the pitch angle, emphasising how it affects the drone's forward or backward motion.
  d) Discuss the importance of pitch control for maneuvering and changing the drone's altitude during flight.

- **Combined Yaw and Pitch Control:**

  a) Integrate both yaw and pitch movements to demonstrate simultaneous control using thrust vectoring.
  b) Perform coordinated maneuvers such as banking turns while maintaining forward motion to showcase the versatility of thrust vectoring.

Check Your Progress

A. Multiple Choice Question

1. What does the left joystick on most drone controllers typically control?
a) Pitch (forward/backward)
b) Roll (left/right)
c) Throttle (up/down) and yaw (rotation)
d) GPS connectivity

2. Which of the following should be checked during pre-flight checks?
a) Drone’s weight
b) Firmware version and battery level
c) Drone color and design
d) Number of propellers

3. What is the first step to take when performing a demo flight?
a) Lift off and fly to a high altitude
b) Perform pre-flight checks
c) Change the battery
d) Adjust the camera settings

4. Which action is critical during the 'Take-Off & Flight' phase?
a) Sudden movements to test responsiveness

b) Gradually increasing throttle to lift off
c) Ignoring the battery level to conserve power
d) Immediately flying at maximum altitude

5. What is a key safety protocol before flying a drone?
a) Perform pre-flight checks to ensure all components are functioning
b) Turn off all sensors
c) Fly at maximum speed
d) Ignore weather conditions if you're experienced

6. What should be done when approaching the landing spot?
a) Perform sharp turns to reduce speed
b) Hover 1-2 meters above the landing area to ensure stability
c) Increase the throttle to quickly descend
d) Ignore the weather conditions

7. When landing a drone, what should you avoid doing?
a) Gradually reducing the throttle
b) Making abrupt movements or sudden cuts to throttle
c) Hovering to stabilize the landing
d) Inspecting the drone for damage after landing

Answer Key

Module 1: SAFETY REGULATIONS AND PROCEDURES IN DRONE OPERATION

Session 1: Safety regulations and guidelines

A. Multiple Choice Questions

1. (b)
2. (b)
3. (c)
4. (c)
5. (b)
6. (a)
7. (c)
8. (b)
9. (d)
10. (b)

Session 2: Multirotor Drone Security Regulations and Protocols

A. Multiple Choice Questions

1. (b)
2. (b)
3. (b)
4. (c)
5. (c)
6. (b)
7. (c)
8. (b)
9. (c)

Module 2: EMERGENCY PROCEDURES IN DRONE FLYING

Session 1: General Emergency Procedures for Drone Operations

A. Multiple Choice Questions

1. (b)
2. (b)
3. (c)
4. (b)

5. (a)
6. (b)
7. (b)
8. (b)
9. (b)
10. (b)

Session 2: In-Flight Emergency Procedures and Crisis Management

A. Multiple Choice Questions

1. (b)
2. (b)
3. (c)
4. (b)
5. (b)
6. (b)
7. (b)
8. (b)
9. (d)
10. (b)

MODULE 3: AIRSPACE PLANNING FOR MULTIROTOR DRONE FLIGHTS

Session 1: Fundamental Principles of Drone Flying

A. Multiple Choice Questions

1. (b)
2. (d)
3. (c)
4. (c)
5. (d)
6. (b)
7. (a)
8. (c)
9. (d)
10. (a)

Session 2: Mission Planning for Multirotor Drones

A. Multiple Choice Questions

1. (b)
2. (a)
3. (b)
4. (c)

5. (b)
6. (d)
7. (b)

Session 3: Drone Flight Mission Plan

A. Multiple Choice Questions

1. (c)
2. (c)
3. (d)
4. (b)
5. (c)

Session 4: Mission Operations Overview

A. Multiple Choice Questions

1. (a)
2. (b)
3. (b)
4. (c)
5. (b)
6. (b)
7. (b)

Module 4: OPERATING A MULTIROTOR DRONE

Session 1: Multirotor Drone Flying Expertise

A. Multiple Choice Questions

1. (c)
2. (b)
3. (b)
4. (b)
5. (c)
6. (c)
7. (c)
8. (c)
9. (c)
10. (d)

Session 2: Essential Skills for Multirotor Drone Flight

A. Multiple Choice Questions

1. (c)

2. (b)
3. (b)
4. (b)
5. (a)
6. (b)
7. (b)

Glossary

Aileron: An aileron is a flight control surface on an aircraft or drone that controls the vehicle's roll. By tilting or rotating the drone's body to the left or right, the ailerons help change its direction, enabling smooth turns. The ailerons work in pairs: when one aileron moves up, the other moves down, creating a differential lift force that rolls the aircraft. This is crucial for controlling the drone's orientation during flight, especially in turns or maneuvers.

Airworthiness: In the context of drones, airworthiness refers to the condition of a drone being fit for safe operation, meeting all relevant design, construction, and maintenance standards. It ensures the drone is reliable and capable of safe flight without posing risks to people, property, or other aircraft.

Altitude: The height of the drone above the ground or sea level, which can be adjusted for various flight maneuvers and patterns.

Autonomous Flying: The capability of a drone to operate and navigate without direct human control, relying on AI, sensors, and algorithms for decision-making and movement.

Autostabilisation Mode: A flight mode that automatically assists in maintaining the drone's stability and attitude, using sensors and gyroscopes to correct deviations and counteract disturbances.

Bank Angle Control: It refers to the manipulation of the drone's tilt or roll during a turn. It involves adjusting the angle at which the drone is inclined sideways, typically to the left or right, in order to change direction.

Banked turns: Banked turns are when a drone tilts its body sideways during a turn, using roll to change direction effectively.

Barrel roll: A barrel roll is an aerial maneuver in which the drone or aircraft rotates 360 degrees around its longitudinal axis (the axis that runs from nose to tail) while following a helical (spiral) flight path. Unlike a simple roll, which is a quick rotation around the axis, a barrel roll combines roll with a slight curve, creating a smooth, controlled loop. This maneuver is often used to demonstrate advanced flight control and agility.

Calibration: Calibration of a drone ensures accurate sensor and system functionality.

Cloud Services for Drones: It refer to the use of cloud computing technology to enhance the capabilities and functionalities of drones.

Cloverleaf Pattern: A flight pattern involving four 90-degree turns arranged in a cloverleaf shape, used to refine precise turning and altitude control.

Collision Avoidance: The ability of a drone to detect and avoid obstacles in its flight path, often supported by advanced algorithms and sensor technologies.

Controller Layout: The arrangement and functions of the controls on a drone's remote controller, including joysticks for throttle, yaw, pitch, and roll.

Counter-drone technology: It refers to systems and methods used to detect, track, identify, and neutralize unauthorized or potentially harmful drones to ensure security.

Data Anonymization: It is the process of removing or altering personal identifiers from data sets, ensuring that individuals cannot be easily identified or linked to the information, while still allowing for the data to be used for analysis or research purposes.

Data Collection: The process of gathering information using drone-mounted sensors and cameras for various applications such as imaging, video footage, or environmental monitoring.

Figure-Eight Pattern: A flight pattern involving a smooth, continuous figure-eight shape, used to improve coordination and control during directional changes.

Flight Patterns: Specific paths or routes that a drone follows during flight, such as figure-eight, square, circle, or S-curve patterns, used to enhance maneuverability and control.

Flyaways: It refer to situations where a drone loses control or connection with the remote controller, causing it to fly uncontrollably, often drifting away from the operator.

GPS: Global Positioning System, used by drones for navigation, providing real-time location and altitude information.

Gyroscopes: Gyroscopes are devices that measure or maintain orientation using rotational motion.

Hovering: The ability to maintain a stationary position in the air, requiring minimal stick movements to counteract drift and maintain altitude.

Joystick: It typically consists of a stick that can be moved in different directions (up, down, left, right) to control movement. In the context of drones, a joystick is used to control various flight functions such as altitude (throttle), direction (yaw), pitch, and roll, allowing the operator to maneuver the drone in all directions.

Manual Control: The direct handling of a drone's flight using the remote controller, as opposed to relying on automated systems or autopilot features.

Mission planning app A mission planning app helps design and optimize drone flight paths, manage waypoints, monitor real-time data, and ensure safety.

Multirotor Drone: A type of unmanned aerial vehicle (UAV) that uses multiple rotors for lift and control, typically categorized by the number of rotors such as quadcopters or hexacopters.

Oval Pattern: A flight pattern where the drone flies in an elongated circular shape, focusing on maintaining consistent bank angles and adapting to changes in airspeed.

Precision Hovering: The skill of keeping the drone precisely over a fixed point, requiring fine control adjustments to maintain stability and resist drift.

Pre-Flight Checks: A series of inspections and verifications performed before drone flight, including battery level, propeller condition, firmware updates, and GPS connectivity.

Remote Controller: The device used by a pilot to control a drone, featuring joysticks and buttons to manage flight controls such as throttle, yaw, pitch, and roll.

Safety Protocols: Procedures and guidelines followed to ensure safe drone operation, including pre-flight checks, emergency landing techniques, and adherence to regulations.

S-Curve Pattern: A flight pattern involving a series of connected curves, resembling an "S," used to practice smooth and coordinated directional changes.

SD cards (Secure Digital cards) : The are portable storage devices used to store data, including images, videos, and files, on electronic devices.

Square Pattern: A flight pattern where the drone flies in a square shape, making 90-degree turns at each corner, used to practice precision and control.

Stabilization: The technology or system that helps maintain a drone's stable flight, counteracting disturbances like wind and turbulence.

Take-off: The process of lifting a drone from the ground into the air, involving gradual throttle increase and careful control to achieve stable ascent.

Telemetry data: It refers to real-time information transmitted from the drone, including location, speed, altitude, battery status, and sensor readings.

Thrust vectoring: It is a technique used in drone and aircraft flight systems where the direction of the thrust produced by the engines or rotors is manipulated to control the vehicle's orientation and maneuverability.

Yaw Control: The ability to rotate the drone around its vertical axis, altering the direction the drone faces, typically controlled by the left stick on mode 2 controllers.

PSS CENTRAL INSTITUTE OF VOCATIONAL EDUCATION

(a constituent unit of NCERT, under Ministry of Education, Government of India)

Shyamla Hills, Bhopal- 462 002, M.P., India

http://www.psscive.ac.in