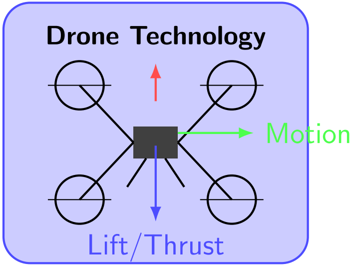
Introduction to Drone Technology

Unit 1

Drone Technology
Gujarat Technological University

Academic Year 2024–25



Unit 1 focus

Definitions, history, classification, terminology, forces, strengths, limitations, and applications of drones.

Unit 1 Roadmap

Eight topics covered in this unit

1. Definitions: UAV, drone, and UAS
2. Historical evolution of drones
3. Classification methods
4. Basic flight terminology
5. Aerodynamic forces and motion
6. Advantages of drones
7. Limitations and constraints
8. Civil and industrial applications

Why this sequence matters

We first define the system, then see how it evolved, how

1. Definitions
↓
2. History
↓
3. Classification
↓
4. Terminology
↓
5. Forces & Motion
↓
6. Advantages
↓
7. Limitations
↓
8. Applications

What is a UAV?

Formal definition

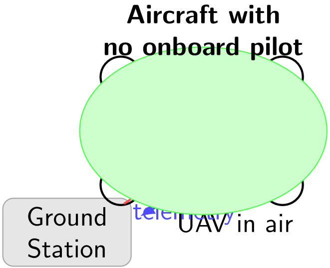
A **UAV** (Unmanned Aerial Vehicle) is an aircraft that flies without a human pilot on board and is controlled remotely, autonomously, or through a hybrid of both modes.

Etymology

Unmanned means no onboard pilot, **aerial** means it operates in the atmosphere, and **vehicle** emphasizes that it is the flying platform itself.

Three key distinctions

- A UAV is the **vehicle only**; it is not the entire operating ecosystem.



What is a Drone?

Informal modern meaning

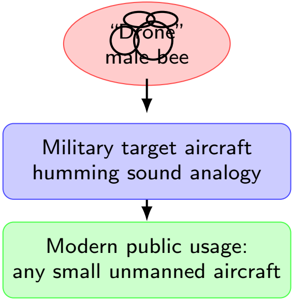
Drone is the common everyday word for an unmanned flying machine. It is widely used in media, industry, education, and public discussion.

Origin of the word

The word is commonly linked to the male bee, whose steady humming sound resembles the sound of early target aircraft. The term became popular through military usage for pilotless target and reconnaissance aircraft.

UAV vs Drone

- **UAV** is the precise engineering/regulatory term.

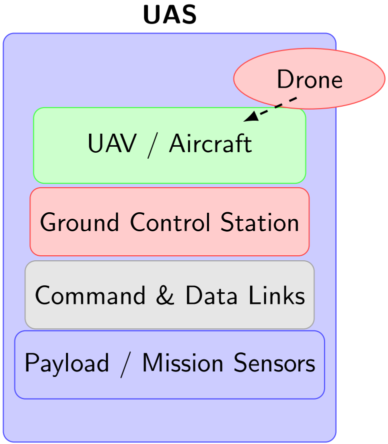


Formal: UAV
Informal: Drone
Casual speech: often mixed

UAV vs UAS vs Drone

Detailed comparison

Term	Scope	Typical usage and meaning
UAV	Vehicle only	The flying platform: airframe, motors, propellers, battery, flight controller, and onboard sensors.
UAS	Complete system	UAV + ground control station + communication links + payload + operators + software + procedures.
Drone	Informal umbrella word	Everyday term used for consumer, commercial, military, and hobby platforms; sometimes means UAV, sometimes the full system.



Exam-ready statement

History of Drones: Ancient to Pre-WWI

Early origins

- In **1849**, Austria used bomb-carrying balloons against Venice. These were not reusable aircraft, but they introduced the idea of striking a target without an onboard pilot.
- In the late 19th century, remote control and automatic stabilization concepts matured through work on radio control and gyroscopes.
- In **1916**, the **Hewitt–Sperry Aerial Torpedo** combined gyroscopic stabilization, preset control, and pilotless flight ideas.

Why this period matters

The core concept of unmanned flight appeared much

1849
Austrian
against Ven

1898
remote control
concepts expand

1916
Hewitt–Sperry
Aerial Torpedo

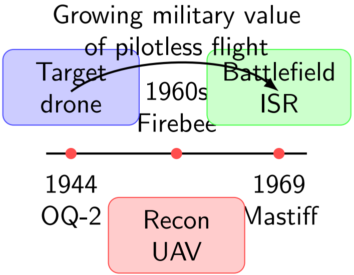
History: WWII to Cold War Era

Key milestones

- **1944 – OQ-2 Radioplane:** among the first mass-produced pilotless target aircraft used for anti-aircraft gunnery practice.
- **1960s – Ryan Firebee:** jet-powered reconnaissance UAV family used for surveillance in contested areas.
- **1969 – Israeli Mastiff:** tactical battlefield drone that demonstrated the value of real-time intelligence and live video relay.

Strategic shift

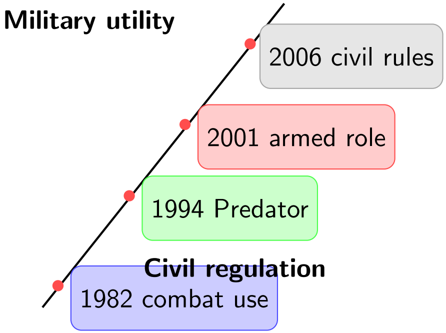
During this period, drones moved from target practice tools to serious reconnaissance assets, especially where



History: Modern Era, 1982–2010

Operational breakthroughs

- **1982 Israel–Lebanon war:** drones were used for decoys, surveillance, and support to suppress enemy air defenses.
- **1994 Predator first flight:** persistent surveillance with long endurance and live video changed modern ISR doctrine.
- **2001 armed Predator strikes:** drones became platforms for both sensing and engagement.
- **2006 FAA commercial rules:** civilian regulatory thinking accelerated as drones moved beyond the military domain.



Main lesson

History: Consumer Revolution, 2010–2025

Mass adoption phase

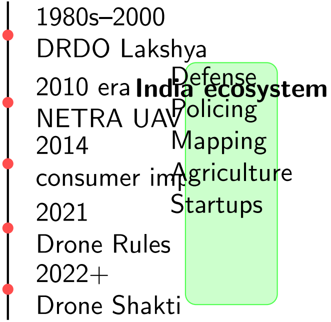
- **2013 Amazon Prime Air:** pushed public imagination toward parcel delivery and last-mile logistics.
- **2013 DJI Phantom 1:** made stabilized quadcopters accessible to consumers and creators.
- **2016 FAA Part 107:** standardized the small commercial drone framework in the United States.
- **2021 India Drone Rules:** simplified compliance and encouraged local adoption.
- **2022 Drone Shakti:** policy attention increased toward agriculture, startups, and service providers.

Technology drivers

India Drone History Timeline

India-specific milestones

- **DRDO Lakshya:** indigenous pilotless target aircraft program strengthened domestic defense UAV capability.
- **NETRA UAV:** compact multirotor platforms from Indian industry popularized police, disaster, and urban surveillance use.
- **2014 consumer imports:** widespread DJI availability expanded hobby, media, and survey usage.
- **2021 Drone Rules:** reduced paperwork, cut forms, and signaled a pro-industry regulatory environment.
- **Drone Shakti and PLI era:** government support boosted startups, training, agriculture, and



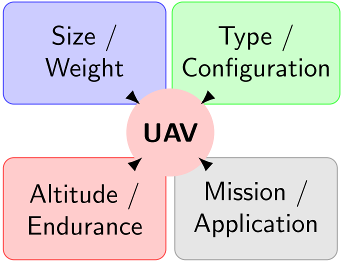
Classification Overview

Why classify drones?

Classification helps engineers choose suitable designs for payload, endurance, regulatory category, mission environment, and control complexity.

Four common methods

- By **size / weight**
- By **airframe type** or aerodynamic configuration
- By **operating altitude / endurance**
- By **mission or application** such as survey, delivery, or combat

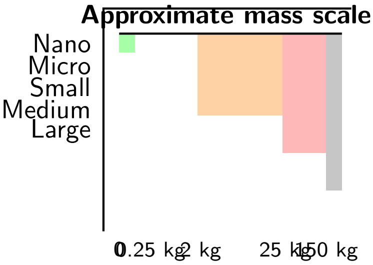


Unit emphasis

Classification by Size / Weight

DGCA-oriented weight classes

Class	Weight limit	Typical examples
Nano	≤ 250 g	Toy drones, palm-sized selfie drones, basic indoor training platforms
Micro	> 250 g to ≤ 2 kg	DJI Mini class, small camera quadcopters, campus inspection drones
Small	> 2 kg to ≤ 25 kg	Survey multirotors, agricultural sprayers, mapping VTOLs
Medium	> 25 kg to ≤ 150 kg	Heavy industrial UAVs, larger logistics or defense support systems
Large	> 150 kg	Strategic military UAVs or aircraft-scale unmanned systems



Design implication

Classification by Type: Fixed-Wing UAV

Core idea

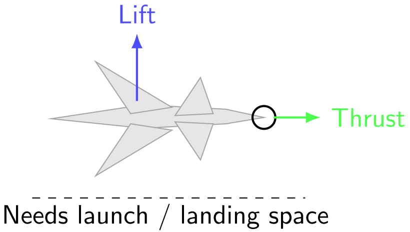
A fixed-wing UAV generates lift using stationary wings while forward thrust is produced by a propeller or jet engine.

Advantages

- High endurance and long range
- Better cruise efficiency than multirotors
- Higher speed and larger area coverage

Disadvantages and examples

- Cannot hover; usually needs runway, launcher, or recovery system



Classification by Type: Single-Rotor Helicopter

Construction

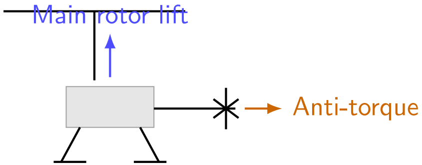
A single-rotor UAV has one large main rotor for lift and thrust vectoring, and a tail rotor or anti-torque mechanism to balance fuselage rotation.

Advantages

- Can hover like a multirotor
- Higher payload capacity than many small multirotors
- Good endurance when engine-powered

Trade-offs and examples

- Mechanical complexity is high: rotor head, transmission, vibration control



Hover + heavier payloads

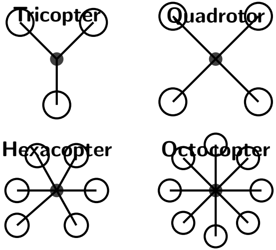
Classification by Type: Multirotor Configurations

General characteristics

Multirotors control motion by changing rotor speeds. They offer vertical takeoff, hover, precise low-speed control, and simple deployment.

Common forms

- **Tricopter (3 rotors):** lighter, less common, often uses a tail-tilt mechanism.
- **Quadrotor (4 rotors):** most common consumer and academic platform.
- **Hexacopter (6 rotors):** better payload and some fault tolerance.
- **Octocopter (8 rotors):** high lift for cinema, LiDAR, or industrial payloads.



Classification by Type: Hybrid VTOL

Concept

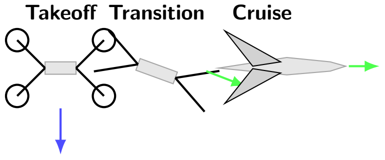
A hybrid VTOL drone combines **vertical takeoff and landing** capability with **fixed-wing cruise efficiency**. It uses rotors for takeoff/landing and wings for efficient forward flight.

Why it is attractive

- No runway required
- Better range than pure multirotors
- Suitable for mapping large areas from small launch sites

Engineering challenge

The most demanding phase is **transition**: the aircraft



Hover → Transition → Efficient cruise

Classification by Altitude

Altitude-based classes

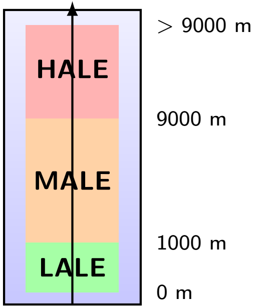
Class	Altitude range	Endurance	Examples
LALE	Below 1000 m	0.5–6 h	Survey multirotors, small VTOLs, local inspection drones
MALE	1000–9000 m	12–40 h	MQ-1 Predator, Heron-class systems
HALE	Above 9000 m	24 h to days	RQ-4 Global Hawk, solar high-altitude platforms

Interpretation

Altitude class often correlates with endurance, mission scale, communication architecture, and military/strategic value.

Important caution

Operating altitude

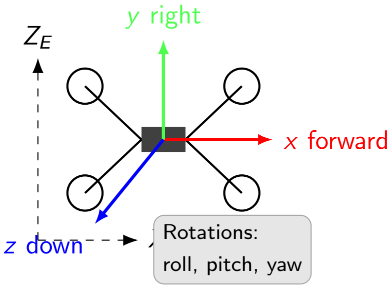


Basic Terminology: Coordinate System and 6-DoF

Body frame axes

For a drone body, the standard aerospace convention is:

- x-axis: forward
- y-axis: right side
- z-axis: downward (body-fixed convention)



Inertial frame

The inertial or earth frame is a fixed reference used to describe position, heading, altitude, and navigation relative to the outside world.

6 Degrees of Freedom

A drone has **3 translational motions** (surge, sway,

Pitch Motion

Definition

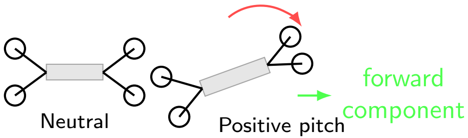
Pitch is rotation about the body y-axis. It changes the nose-up or nose-down attitude of the drone.

Direction and effect

- **Positive pitch:** nose rises
- **Negative pitch:** nose drops
- In forward flight, a multirotor pitches forward so that total thrust gets a forward component.

Analogy

Pitch is similar to tilting your head up and down or a seesaw rotating about its side-to-side axis.



Roll Motion

Definition

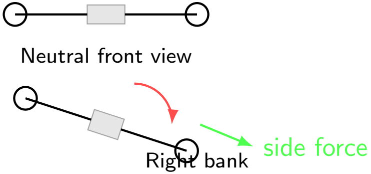
Roll is rotation about the body *x*-axis. It raises one side of the vehicle and lowers the other.

Direction and effect

- **Positive roll** is commonly interpreted in basic UAV teaching as a right bank.
- **Negative roll** corresponds to a left bank.
- A multirotor rolls to produce a sideways component of thrust for lateral motion.

Analogy

Roll is similar to leaning a bicycle or banking an aircraft in a turn.



Yaw Motion

Definition

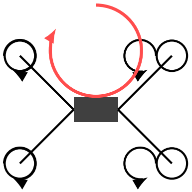
Yaw is rotation about the body z-axis. It changes the heading of the drone without necessarily changing altitude.

Compass interpretation

Yaw determines whether the nose points North, East, South, West, or any intermediate compass direction.

How a quadrotor yaws

A quadrotor uses **differential reaction torque**: increase speed of one rotor pair and reduce the opposite pair so the net lift remains similar but net torque rotates the body.



Heading changes by yaw

CW pair vs CCW pair
torque imbalance

Throttle and Altitude

Throttle

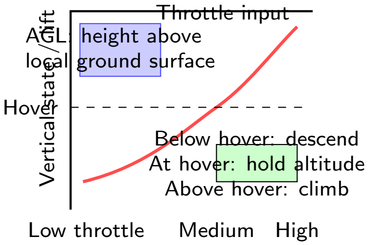
Throttle is the pilot or controller command that changes motor power. Higher throttle generally increases motor RPM, propeller airflow, and thrust.

Altitude concepts

- **AGL** = Above Ground Level
- **AMSL** = Above Mean Sea Level
- The same drone can have low AGL but high AMSL on a mountain plateau.

Hover condition

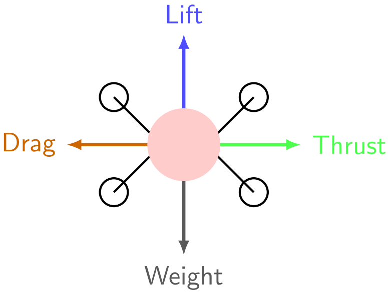
At hover, total thrust equals weight: $T \approx W = mg$. If thrust exceeds weight, the drone climbs; if thrust is



Forces Acting on a Drone

The four main forces

- **Lift**: aerodynamic upward force generated by propellers or wings
- **Weight**: gravitational force acting downward
- **Thrust**: propulsive force pushing the drone through air
- **Drag**: aerodynamic resistance opposing motion



Connection to Newton's laws

- If forces balance, velocity stays constant.
- If net force is non-zero, acceleration occurs.
- For rotation, unbalanced torques change angular motion.

How lift is generated

Drone propellers behave like rotating wings. Each blade section has an airfoil shape and angle of attack that accelerates air downward, creating an upward reaction force.

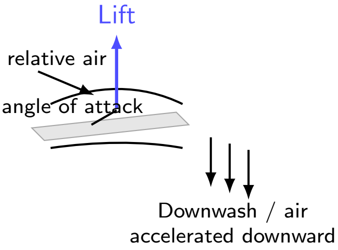
Conceptual lift relation

$$L = \frac{1}{2}\rho v^2 C_L A$$

where ρ is air density, v is airflow speed, C_L is lift coefficient, and A is reference area.

Factors affecting lift

- Higher rotor RPM increases airflow speed



Drag

Definition

Drag is the aerodynamic force that opposes motion through air. As speed increases, drag rises rapidly and reduces efficiency.

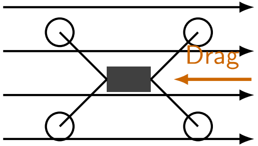
Conceptual drag relation

$$D = \frac{1}{2}\rho v^2 C_D A$$

where C_D is the drag coefficient and A is reference area exposed to airflow.

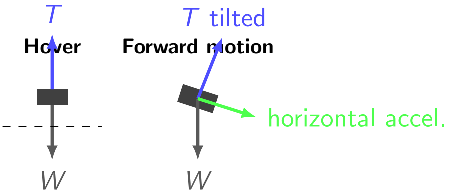
Two common forms

- **Parasitic drag:** from body shape, landing gear, arms, wires, antennas, and payloads



Streamlined body $\Rightarrow$ lower C_D
External payloads $\Rightarrow$ higher drag

Thrust and Gravity



Thrust and weight

- **Thrust** comes from the motor–propeller system pushing air downward or backward.
- **Gravity** pulls the drone downward with force $W = mg$.
- According to Newton's second law, the net force determines acceleration: $\sum F = ma$.

Equilibrium conditions

Condition	Force relation	Meaning
Hover	$T = W$	No vertical acceleration
Ascend	$T > W$	Upward acceleration
Descend	$T < W$	Downward acceleration
Forward	$T = W$	Part of thrust acts

Advantages of Drones

Eight major advantages

1. **Lower cost:** a quadcopter inspection sortie may cost only electricity, crew time, and maintenance, while helicopter charter can exceed Rs. 1 lakh per hour.
2. **No onboard pilot risk:** dangerous missions can be flown without exposing aircrew.
3. **Rapid deployment:** many field drones can be airborne within 5–10 minutes.
4. **High-resolution data:** RGB, thermal, multispectral, and LiDAR payloads provide rich sensing.
5. **Access to hard locations:** towers, cliffs, flood zones, rooftops, and narrow corridors are easier to inspect.
6. **Repeatability:** waypoint flights enable the same route to be flown again for comparison.
7. **Environmental benefit:** electric drones are quieter and

Task metric	Manned aircraft	Drone
Startup time	Hours	Minutes
Pilot risk	Present	None onboard
Close-up imaging	Difficult	Excellent
Energy use for small jobs	High	Low
Farm imaging/day	Limited by cost	100+ ha practical
Repeat path accuracy	Moderate	High with GNSS

Typical wins:
- quick mapping
- safer inspection
- cheaper repeated surveys

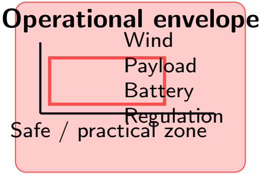
Higher flexibility per rupee

Limitations of Drones

Seven practical limitations

1. **Battery endurance:** many multirotors fly only about 15–30 minutes per battery.
2. **Payload limits:** most small civil drones carry modest payloads; heavy lifting above 25 kg becomes costly and regulated.
3. **Range constraints:** many operations stay within visual line of sight; practical ranges of 2–10 km are common without advanced approvals.
4. **Weather sensitivity:** strong winds above about 25–35 km/h, rain, and dust can degrade safety and image quality.
5. **Navigation dependence:** GNSS loss, magnetic interference, and poor compass calibration can destabilize missions.

Limitation	Typical impact
Short flight time	More batteries, more landings
Low payload	Smaller sensors or shorter endurance
Wind / rain	Mission cancellation or reduced accuracy
Rules / airspace	Delays and restricted routes
GNSS issues	Hover drift, poor repeatability



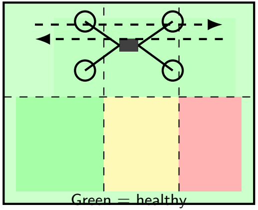
Applications: Agriculture

Major agricultural uses

- Crop monitoring through RGB and multispectral imaging
- NDVI and other vegetation indices for plant health mapping
- Variable-rate spraying based on field condition zones
- Irrigation assessment, stand counting, and pest hotspot detection

India context

Government attention through initiatives such as the **Kisan Drone** push has increased use of drones for precision farming, spraying, and village-level service



Green = healthy
Yellow = stress
Red = urgent attention

Aerial photography and media

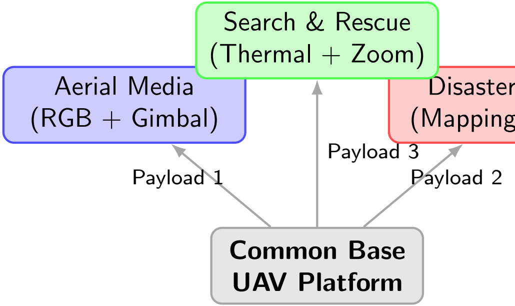
Stabilized gimbals, 4K/8K cameras, and programmable flight paths enable cinematic shots, wedding coverage, real-estate imaging, tourism promotion, and progress documentation.

Disaster management

After floods, landslides, fires, or earthquakes, drones can rapidly produce situational maps, locate blocked routes, and assess damage without first sending people into unsafe zones.

Search and rescue

Thermal cameras, zoom payloads, loudspeakers, and spotlight modules help teams search for missing persons,



Interchangeable Payloads Enable Diverse Mis

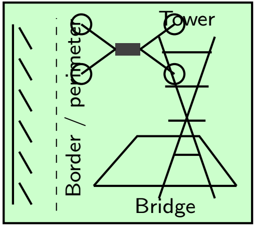
Applications: Surveillance, Security, Infrastructure Inspection

Surveillance and security

- Border patrol, crowd monitoring, event security, traffic observation, and perimeter monitoring
- Useful for real-time overwatch with zoom cameras, thermal imagers, and live video links
- Indian examples include police deployments, corridor monitoring, and border-area observation support

Infrastructure inspection

Drones inspect bridges, towers, transmission lines, pipelines, solar parks, rail corridors, and industrial plants with less shutdown time and less human climbing risk.



Applications: Parcel Delivery, Mapping, Surveying

Parcel delivery

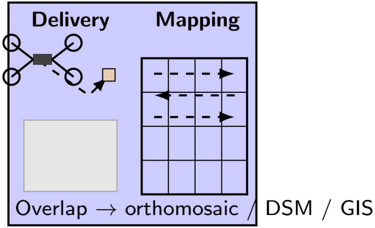
Pilot projects such as **Amazon Prime Air** and Indian food or medical delivery trials show how drones may reduce last-mile travel time for lightweight packages, especially in low-traffic or hard-to-reach routes.

Mapping and surveying

Drones capture overlapping images, often with about **70–80% overlap**, which photogrammetry software converts into orthomosaics, digital surface models, and 3D point clouds.

Why survey teams use drones

- Faster coverage than walking total-station surveys for many terrain types



Summary and Review Questions

Unit summary

- UAV is the vehicle; UAS is the complete operating system.
- Drone history evolved from pilotless weapons and targets to modern commercial platforms.
- Drones can be classified by weight, type, altitude, and mission.
- Body axes and 6-DoF explain orientation and motion.
- Pitch, roll, yaw, throttle, lift, drag, thrust, and weight are core flight concepts.
- Drones provide low-cost, flexible, high-resolution access to the air.

Review questions

1. Define UAV, drone, and UAS with one difference each.
2. Explain two historical milestones before 1950.
3. Compare fixed-wing, single-rotor, multirotor, and hybrid VTOL UAVs.
4. Classify drones by DGCA weight categories with examples.
5. Explain pitch, roll, yaw, and throttle using body axes.
6. Draw and explain the four main forces acting on a drone.
7. State four advantages and four limitations of drones.