Chapter 1

BASICS OF DRONES

Terms related to drones

Drone/Unmanned aerial vehicle :An unmanned aerial vehicle, commonly known as a drone, is an aircraft without any human pilot, crew, or passengers on board.

Range :it is defined as the total distance (measured with respect to ground) traversed by the airplane on a full tank of fuel.

Endurance:it is defined as the total time that an airplane stays in the air on a full tank of fuel.

Wingspan:The wingspan (or just span) of a bird or an airplane is the distance from one wingtip to the other wingtip.

Center of gravity (C.G):it is the average location of all the weight of an object.

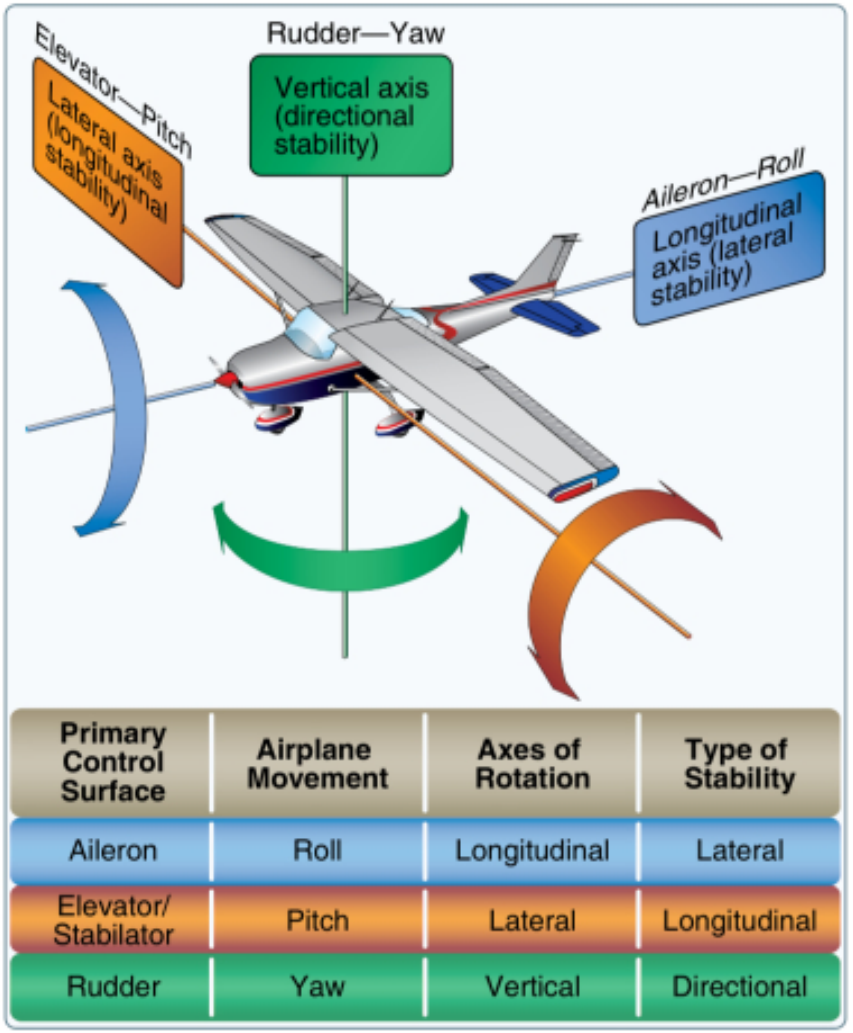
Center of lift(C.L) :it is the point where the sum total of all lift generated by parts

Angle of Attack: Angle of attack is the angle between a reference line on a body and the vector representing the relative motion between the body and the fluid through which it is moving.

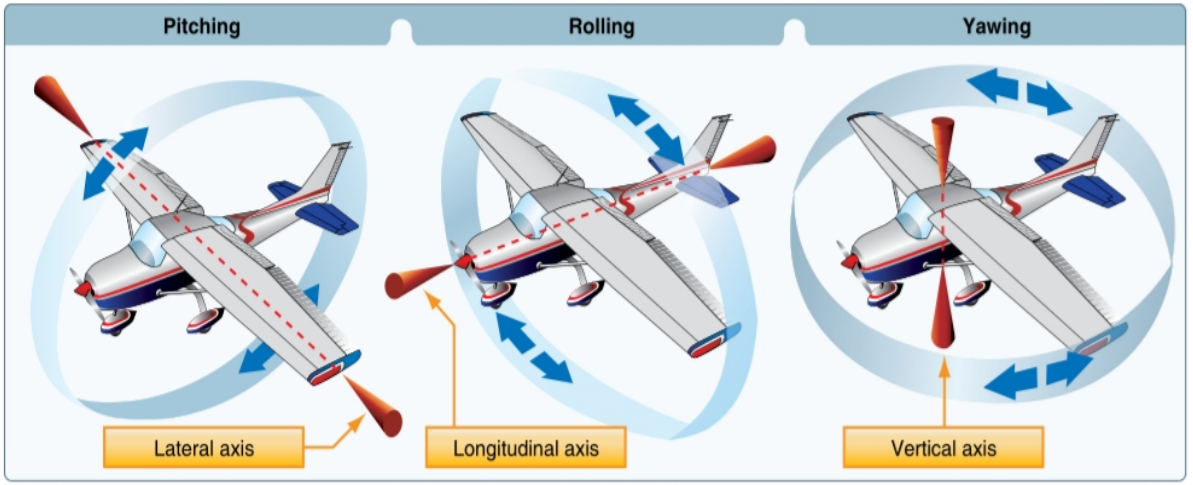
- **Altitude**:Altitude is the height of an object above the surface of the ground or sea level.
- **Hovering**:To remain in one place in the air.
- **Maneuver**:An intended and controlled variation from a straight and level flight path in the operation of an airplane.
- **Surveillance**:Act of watching a person or a place, especially a person believed to be involved with criminal activity or a place where criminals gather.
- **Reconnaissance**:the process of obtaining information about enemy forces or positions by sending out small groups of soldiers or by using aircraft.

- **Unmanned combat aerial vehicle (UCAV)**:It is an unmanned combat aerial vehicle (UCAV), also known as a combat drone, or battlefield UAV, is an unmanned aerial vehicle (UAV) that is used for intelligence, surveillance, target acquisition, and reconnaissance and carries aircraft ordnance such as missiles, ATGMs, and/or bombs in hardpoints for drone strikes.

Motion of aircraft

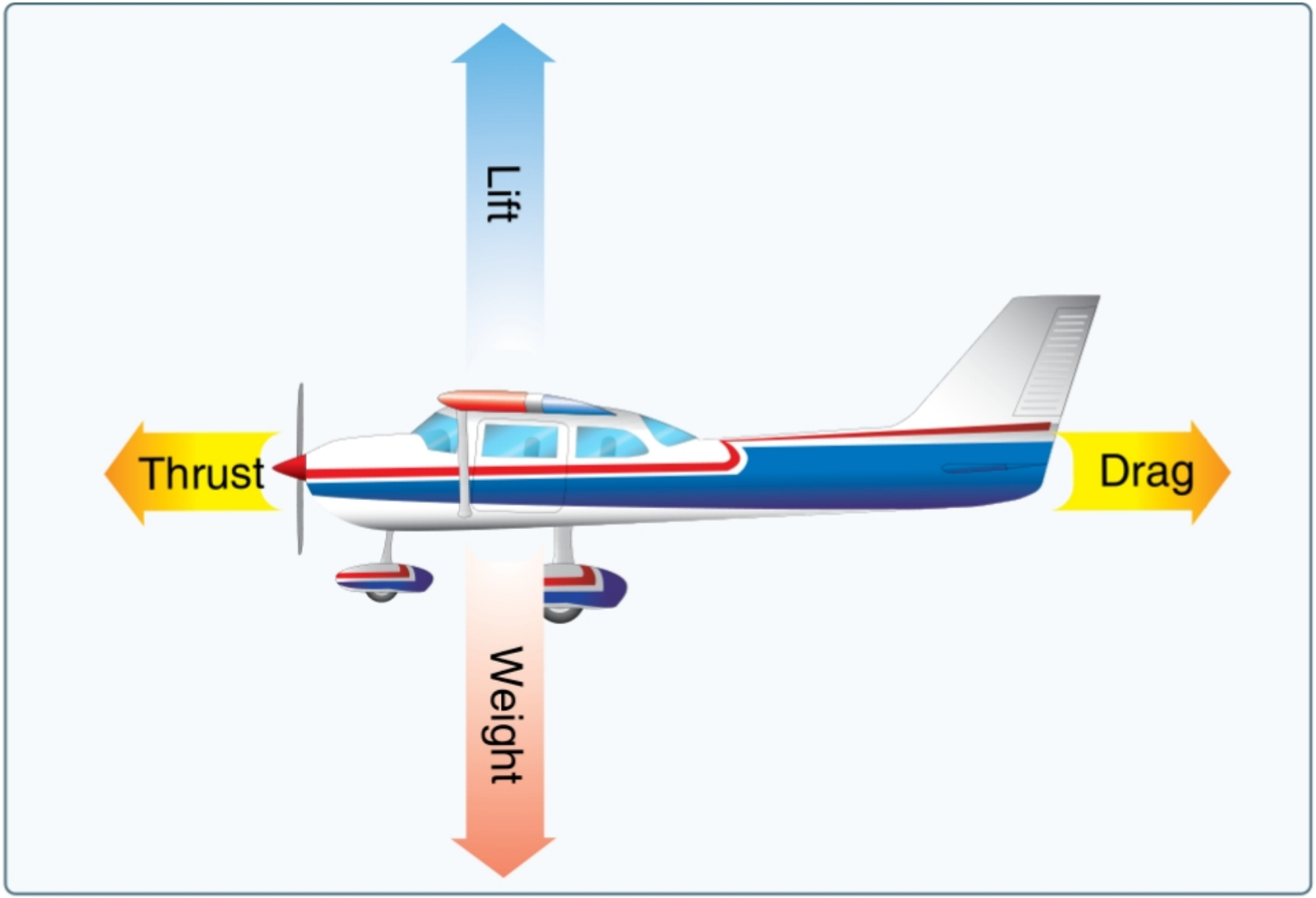


Primary Control Surface	Airplane Movement	Axes of Rotation	Type of Stability
Aileron	Roll	Longitudinal	Lateral
Elevator/ Stabilator	Pitch	Lateral	Longitudinal
Rudder	Yaw	Vertical	Directional

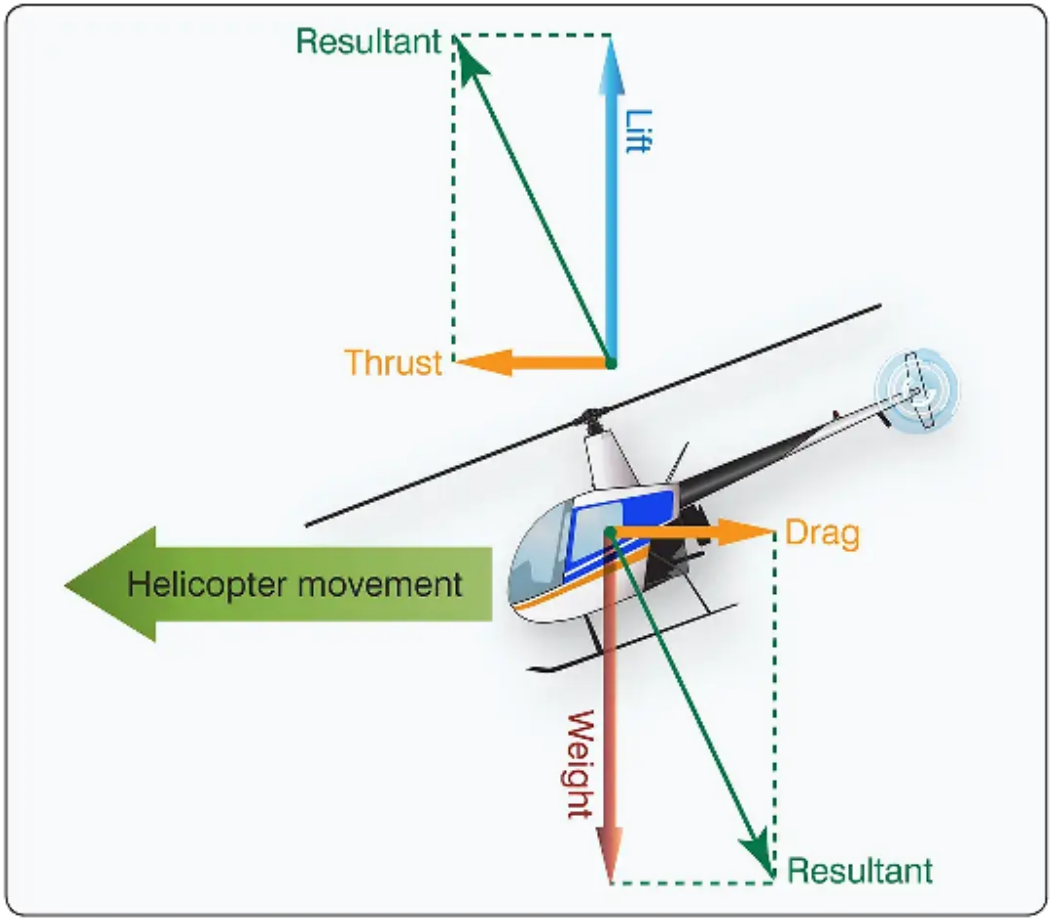


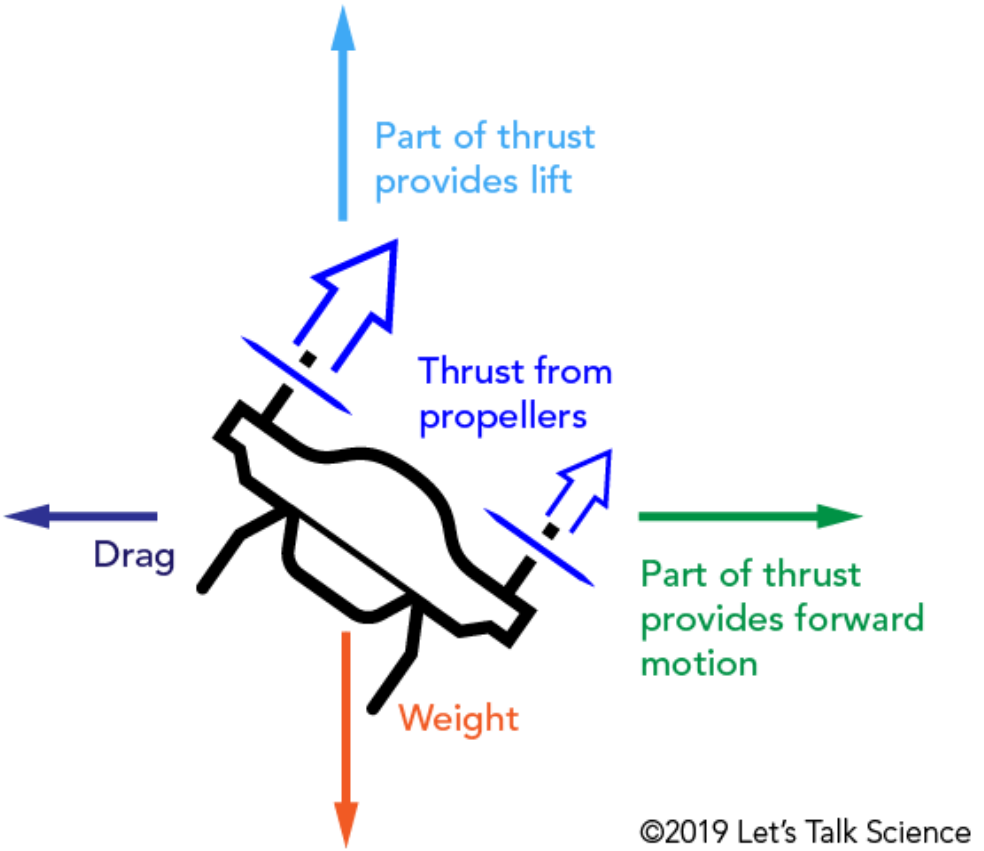
- **Vertical axis, or yaw axis** — an axis drawn from top to bottom, and perpendicular to the other two axes, parallel to the fuselage station.
- **Transverse axis, lateral axis, or pitch axis** — an axis running from the pilot's left to right in piloted aircraft, and parallel to the wings of a winged aircraft, parallel to the buttock line.
- **Longitudinal axis, or roll axis** — an axis drawn through the body of the vehicle from tail to nose in the normal direction of flight, or the direction the pilot face
- **Pitch**:The rotation of aircraft about lateral axis (Nose up or Nose down)
- **Roll**:The rotation of aircraft about longitudinal axis. (BankiBanking left or right)
- **Yaw**:The rotation of aircraft about Vertical axis(Turning left or right)

Forces acting on Aircraft



- **Thrust**—the forward force produced by the powerplant/ propeller or rotor. It opposes or overcomes the force of drag.
- **Drag**—a rearward, retarding force caused by disruption of airflow by the wing, rotor, fuselage, and other protruding objects
- **Lift**—is a force that is produced by the dynamic effect of the air acting on the airfoil, and acts perpendicular to the flight path
- **Weight**—the combined load of the aircraft itself, the crew, the fuel, and the cargo or baggage





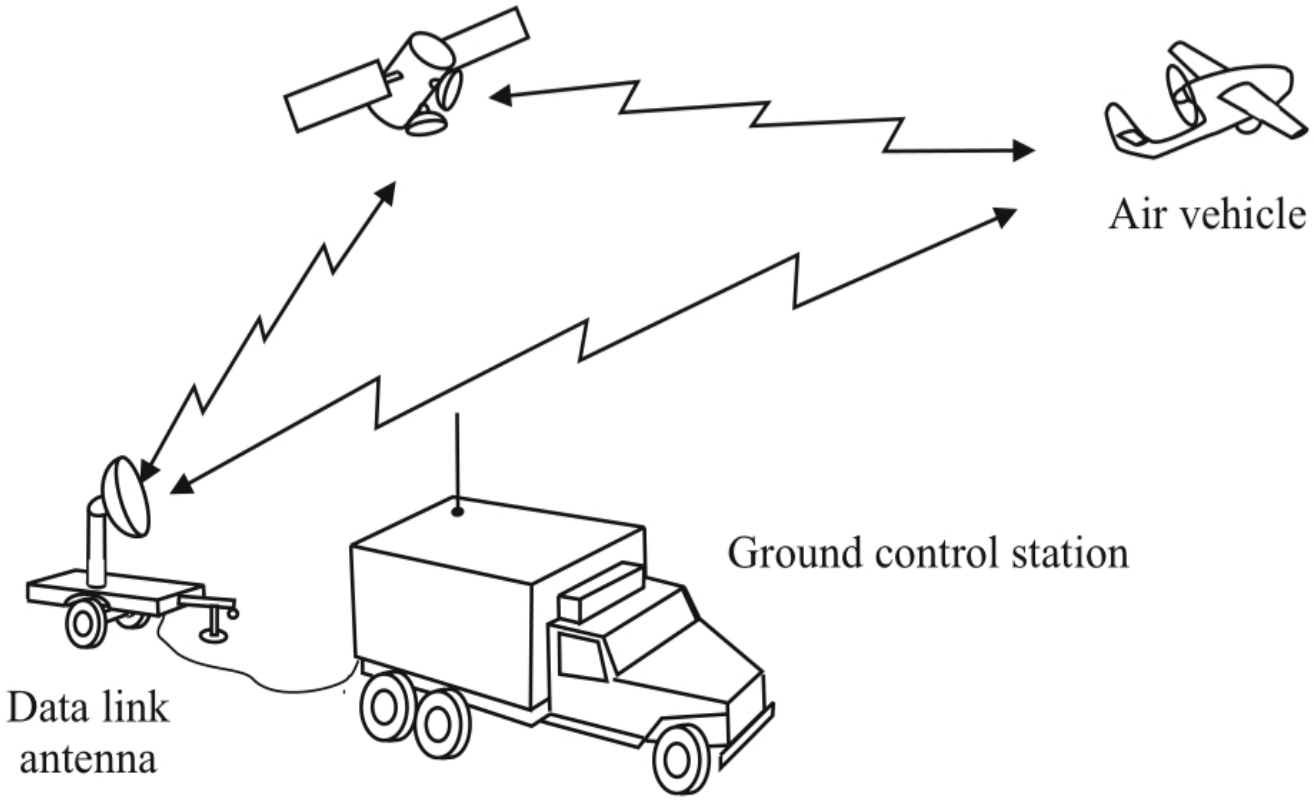
In the case of Rotorcrafts, rotor serves for both lift force for gaining altitude and thrust force for moving forward

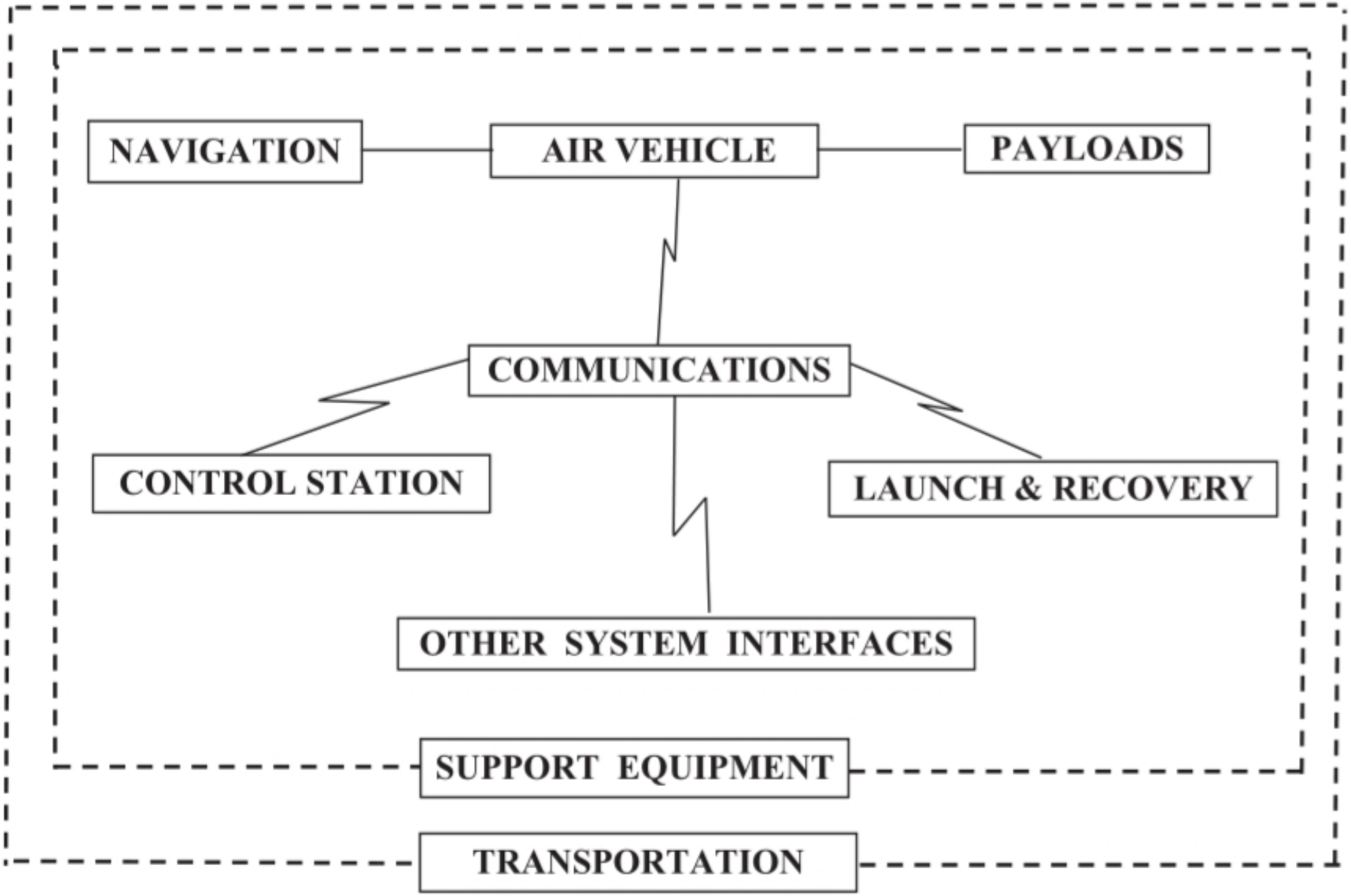
Overview of UAV Systems

Overview of UAV Systems

As a minimum, a typical UAV system is composed of

- Air vehicles,
- One or more ground control station (GCS) and/ or mission planning and control stations (MPCS),
- Payload, and
- Data link



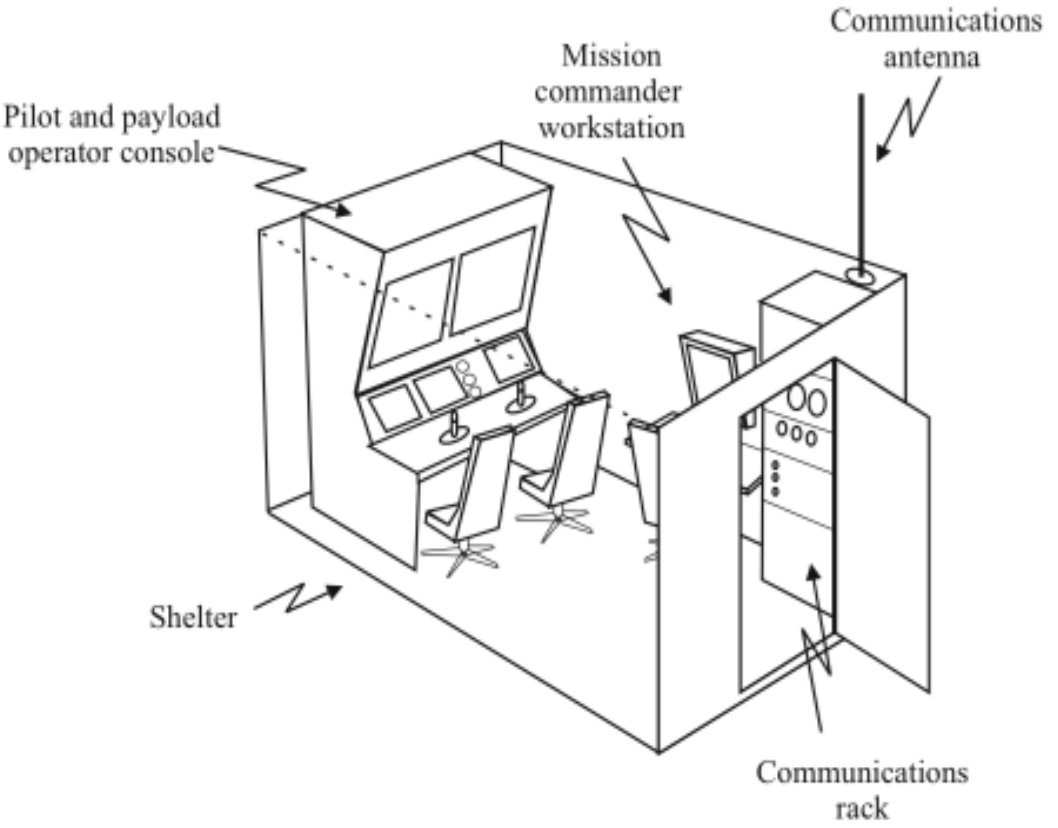


Air Vehicle

- The air vehicle is the airborne part of the system that includes the airframe, propulsion unit, flight controls, and electric power system.
- The air data terminal is mounted in the air vehicle, and is the airborne portion of the communications data link
- The air vehicle can be a fixed-wing airplane, rotary wing, or a ducted fan

Mission Planning and Control Station

- The MPCS, also called the GCS, is the operational control center of the UAV system where video, command, and telemetry data from the air vehicle are processed and displayed.
- The MPCS shelter incorporates a mission planning facility, control and display consoles, video and telemetry instrumentation, a computer and signal processing group, the ground data terminal, communications equipment, and environmental control and survivability protection equipment.



Launch and Recovery Equipment

- Launch and recovery can be accomplished by a number of techniques ranging from conventional takeoff and landing on prepared sites to vertical descent using rotary wing or fan systems.
- Catapults using either pyrotechnic (rocket) or a combination of pneumatic/hydraulic arrangements are also popular methods for launching air vehicles. Some small UAVs are launched by hand, essentially thrown into the air like a toy glider.
- Nets and arresting gear are used to capture fixed-wing air vehicles in small spaces. Parachutes and parafoils are used for landing in small areas for point recoveries.
- One advantage of a rotary-wing or fan-powered vehicle is that elaborate launch and recovery equipment usually is not necessary.

Payloads

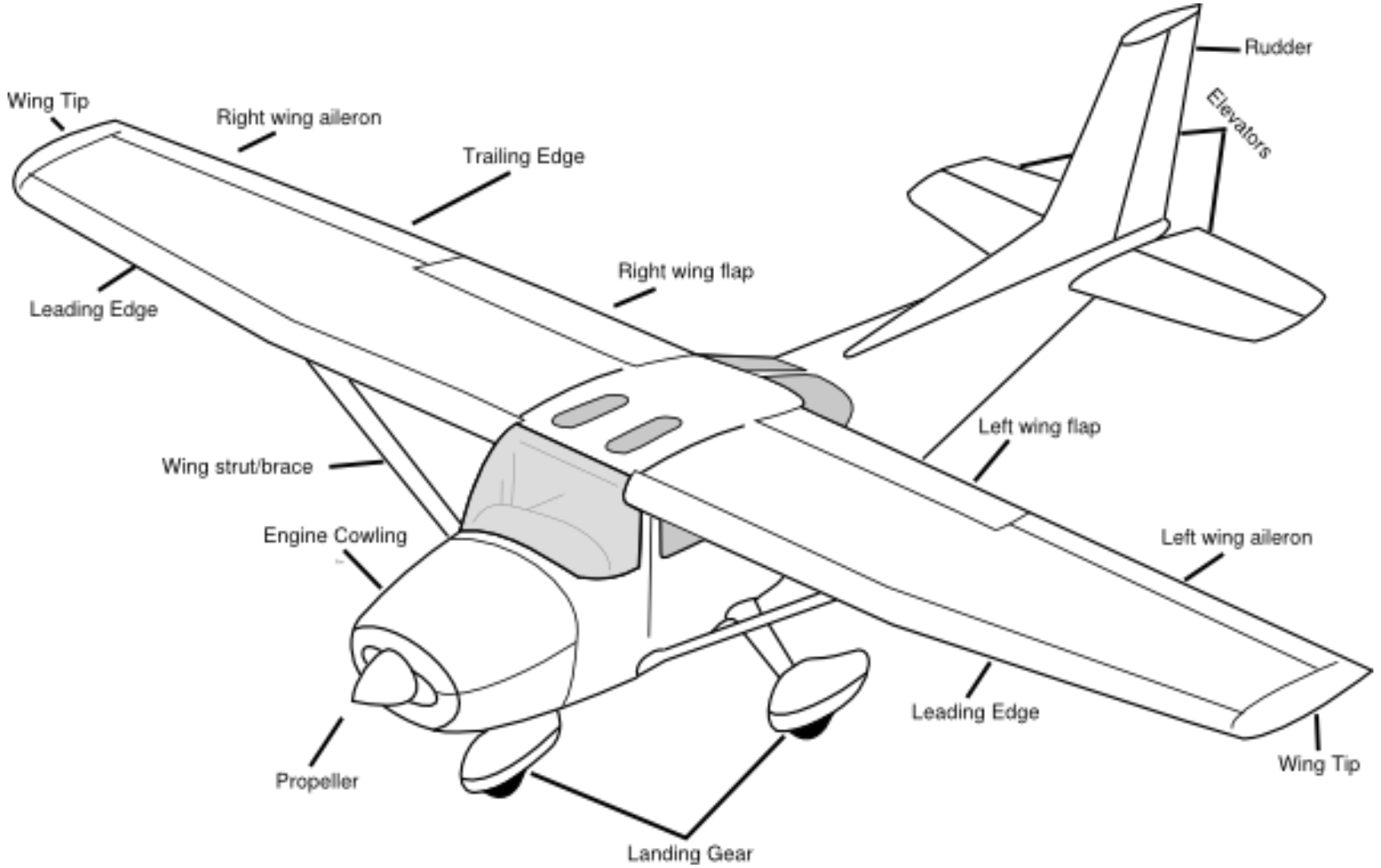
- Payloads often include video cameras, either daylight or night (image-intensif i ers or thermal infrared), for reconnaissance and surveillance missions.
- Radar sensors, often using Moving Target Indicator (MTI) and/or synthetic aperture radar (SAR) technology, are also important payloads for UAVs conducting recon-naissance missions.
- Another major category of payloads is electronic warfare (EW) systems.They include the full spectrum of signal intelligence (SIGINT) and jammer equipment.
- Armed UAVs carry weapons to be fired, dropped, or launched. “Lethal” UAVs carry ex-plosive or other types of warheads and may be deliberately crashed into targets

Ground Support Equipment

- GSE may include: test and maintenance equipment, a supply of spare parts and other expendables, a fuel supply and any refueling equipment required by a particular air vehicle, handling equipment to move air vehicles around on the ground if they are not man-portable or intended to roll around on landing gear, and generators to power all of the other support equipment.
- The GSE must include transportation for all of the things listed earlier, as well as transportation for spare air vehicles and for the personnel who make up the ground crew, including their living and working shelters and food, clothing, and other personal gear.

Parts of UAV

Parts of fixed wing aircraft



Fuselage

The fuselage includes the cabin and/or cockpit, which contains seats for the occupants and the controls for the airplane. In addition, the fuselage may also provide room for cargo and attachment points for the other major airplane components.

Wings

The wings are airfoils attached to each side of the fuselage and are the main lifting devices that support the airplane in flight. Wings may be attached at the top, middle, or lower portion of the fuselage. These designs are referred to as high-, mid-, and low-wing, respectively

Empennage

The empennage (also called tail) is the rear part of the aircraft. Usually it includes the stabilizers, rudder and elevator as many other components.

Propeller :A propeller is a device which transmits power by converting it into thrust for propulsion of a vehicle.The blades of a propeller act as rotating wings, and produce force.

Engine: it provides the power to move the aircraft forward.the power generation mechanism may vary based on the aircraft requirement.

Landing Gear:The landing gear supports the aircraft when it is not flying, allowing it to take off, land, and taxi without damage.

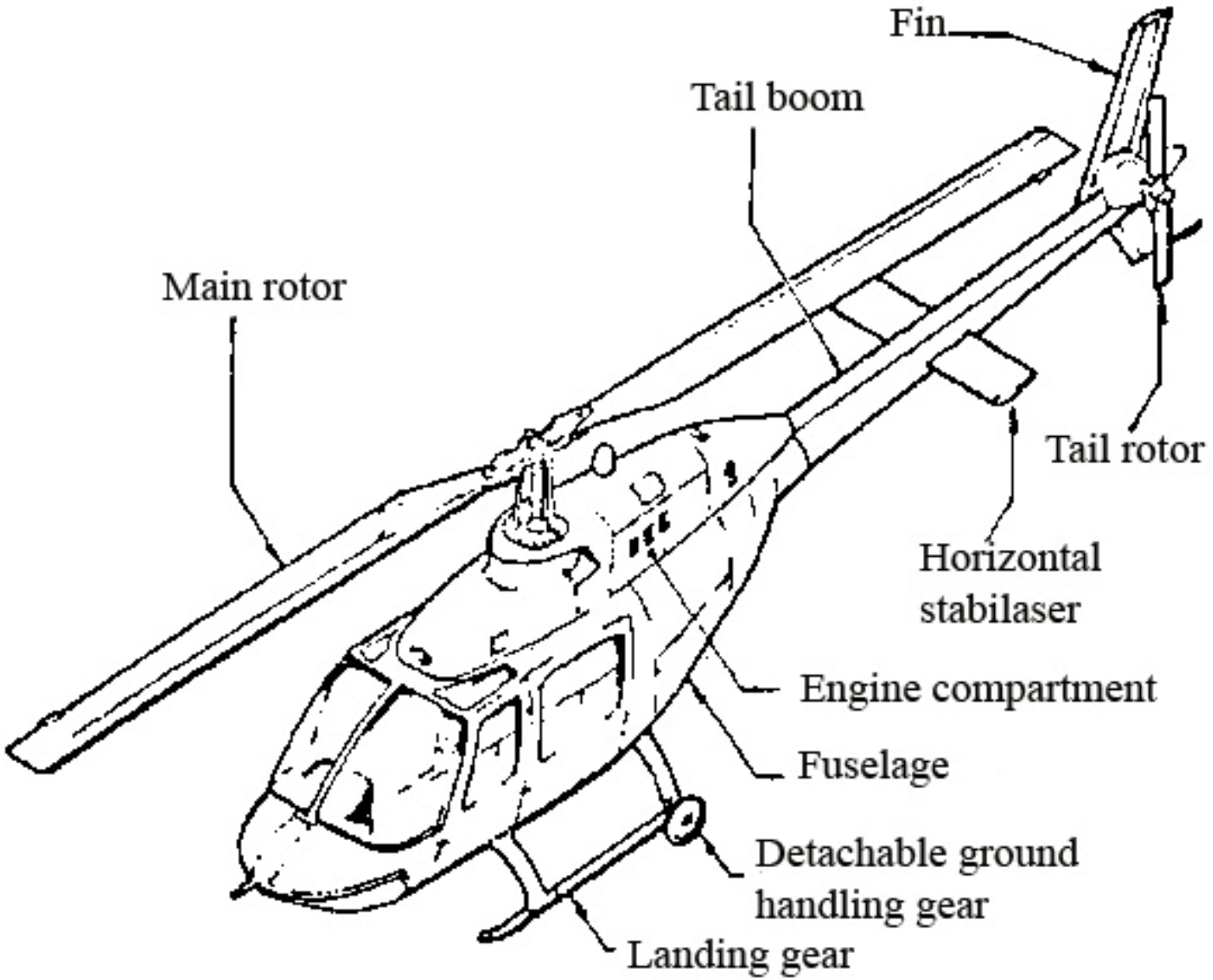
Control surfaces

Aileron:Ailerons are moving surfaces usually placed near the tips of the wings.it is used in rolling of aircraft left or right

Rudder:It is attached to trailing edge of Vertical stabilizer. The rudder controls the Y-axis or Yaw of the plane.

Elevator:it is attached to trailing edge of horizontal stabiliser and is useful in pitching of aircraft up and down.

Parts of rotorcraft



- **Fuselage**: The fuselage, the outer core of the airframe, is an aircraft's main body section that houses the cabin that holds the crew, passengers, and cargo.

- **Main Rotor System**: The rotor system is the rotating part of a helicopter which generates lift. The rotor consists of a mast, hub, and rotor blades.

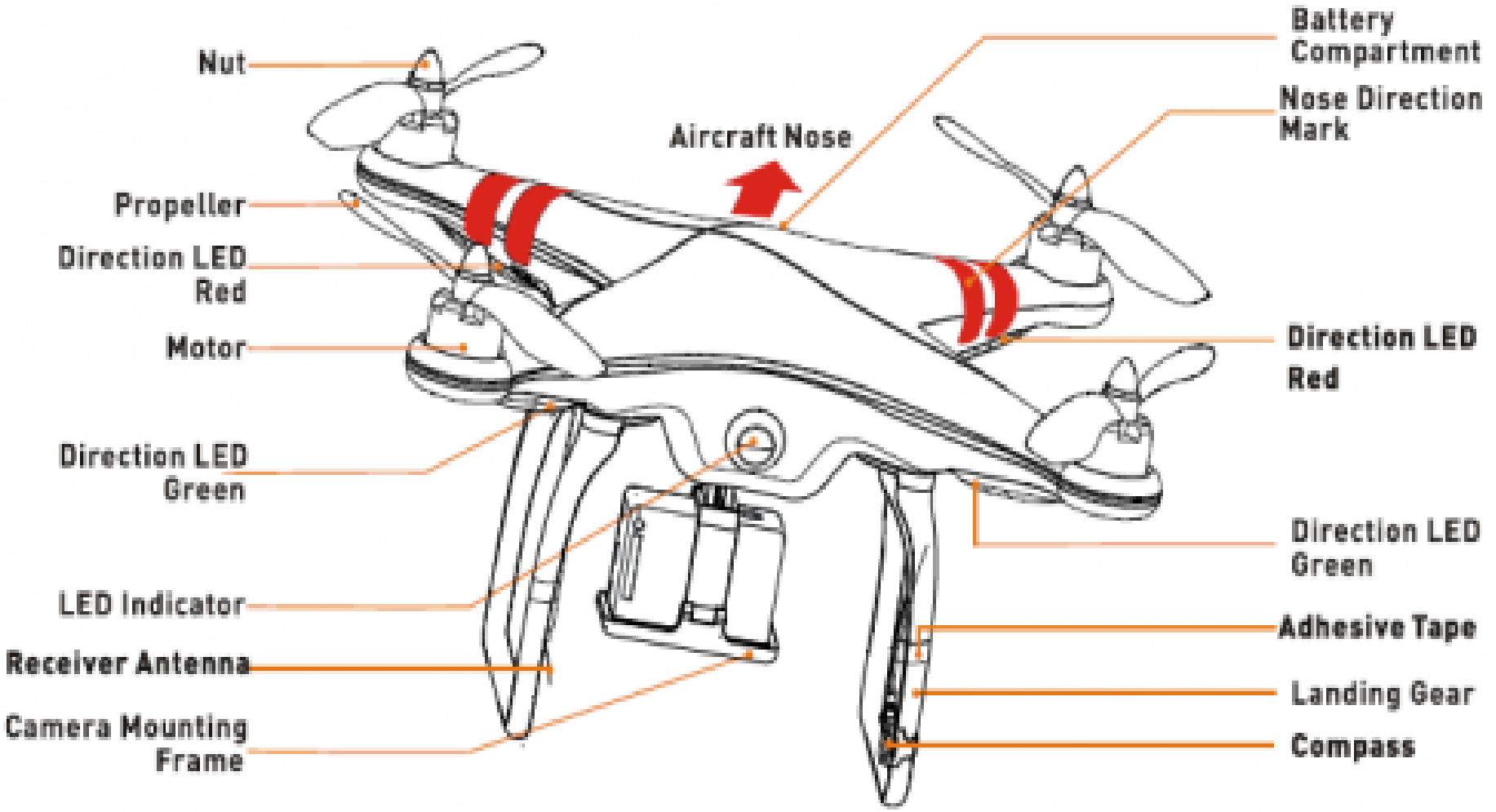
- **Engine**:it provides the power to rotate the rotorblades.Reciprocating engines, also called piston engines, are generally used in smaller helicopters.Turbine engines are more powerful and are used in a wide variety of helicopters

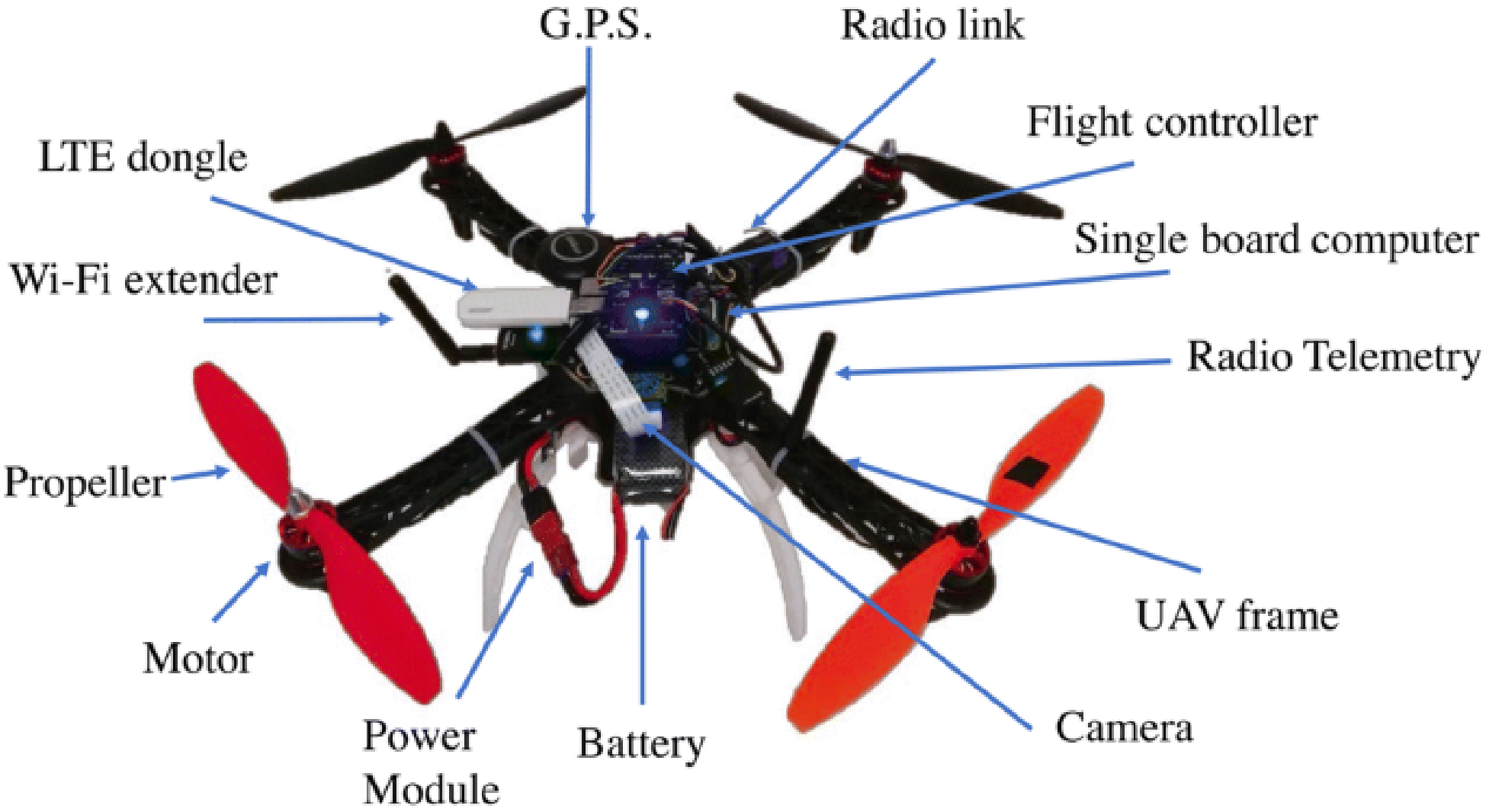
- **Landing Gear**:The landing gear supports the aircraft when it is not flying, allowing it to take off, land, and taxi without damage.

- **Antitorque System**: Helicopters with a single, main rotor system require a separate antitorque system. This is most often accomplished through a variable pitch, antitorque rotor or tail rotor.

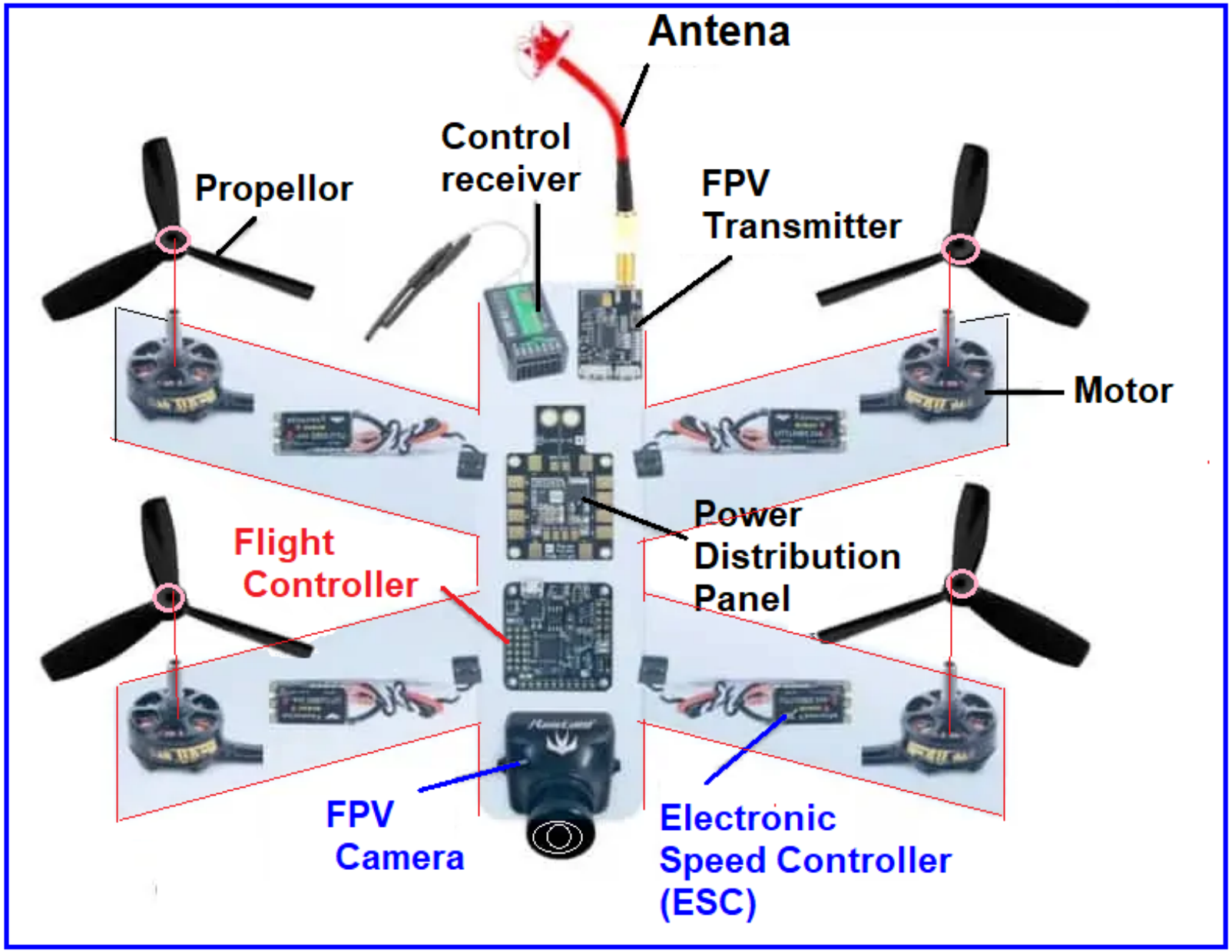
- **Tailboom**:it provides the arm to the tailrotor generated anti-torque force. The tailrotor itself is housed at the end of the tailboom for this reason

Parts of multirotor aircraft





Parts of Drone



A quadcopter consists of the following essential parts:

- Frame
- Motors
- ESC (electronic speed controller)
- Propeller
- Battery
- Flight Controller
- RC Receiver

Frames:It includes arms to hold motors and a chassis to hold the flight controller, battery and other components on board.

Motors:4 motors are must for Quadcopter to lift it up.generally brushless DC motor is used

Propeller:These spinning blades are the wings to your craft, the very part that creates the airflow that lifts the machine into the air.

Battery :it is the power source that drives all the systems on your drone and allows it to fly.generally Lithium polymer battery is used.

Electronic speed controller:it converts the signals from Controller and send it to motors to control its speed.

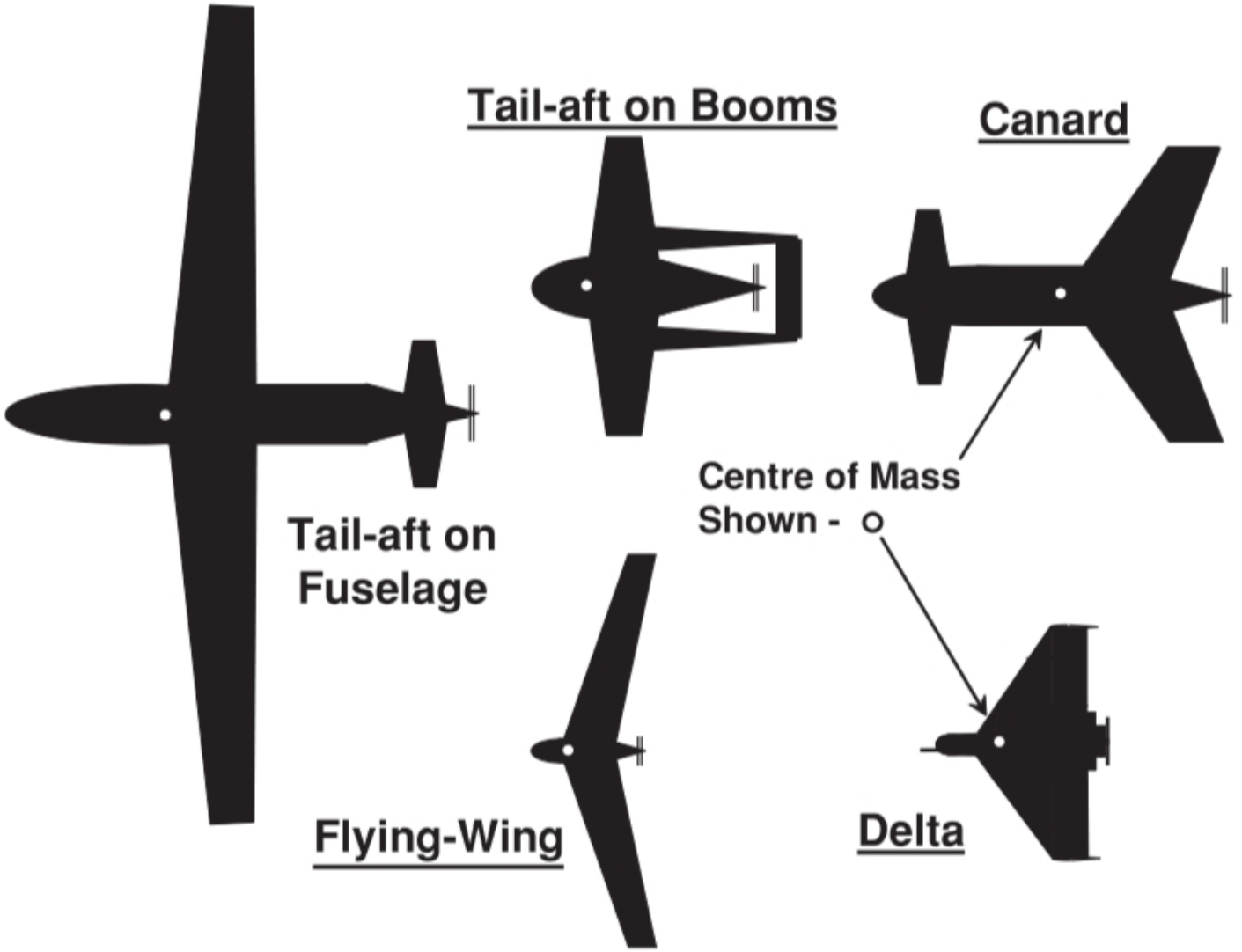
Flight controller:Its function is to direct the RPM of each motor in response to input. A command from the pilot for the Quad-copter to move forward is fed into the flight controller, which determines how to manipulate the motors accordingly.

RC transmitter and receiver:Radio Transmitter is an electronic device that controls the quadcopter manually.

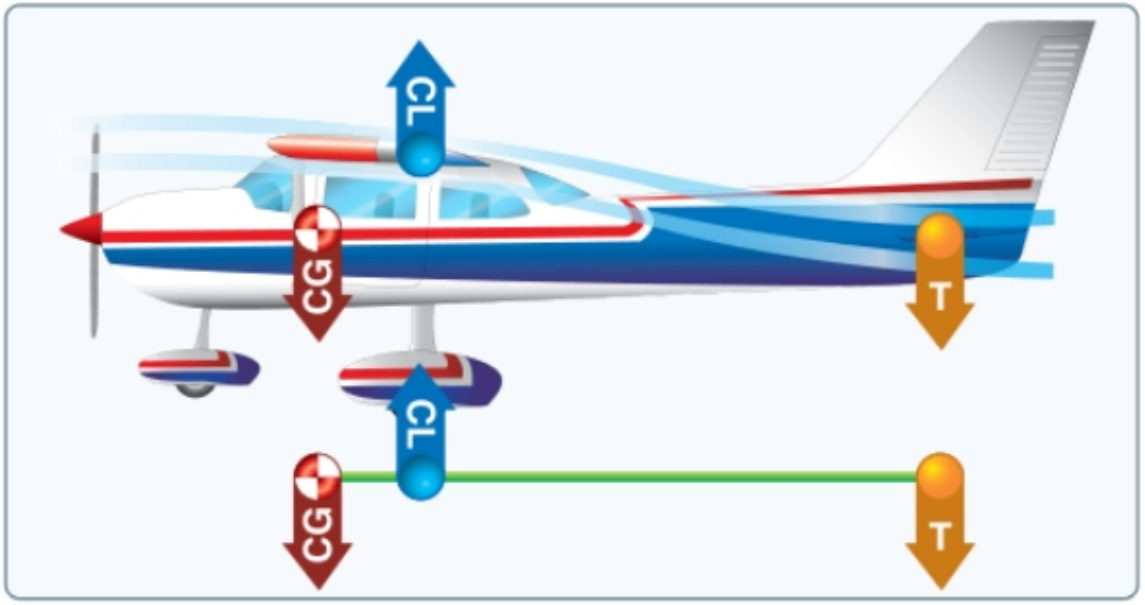
Classification of UAV

Based on airframe

1) HTOL or horizontal take-off and landing:

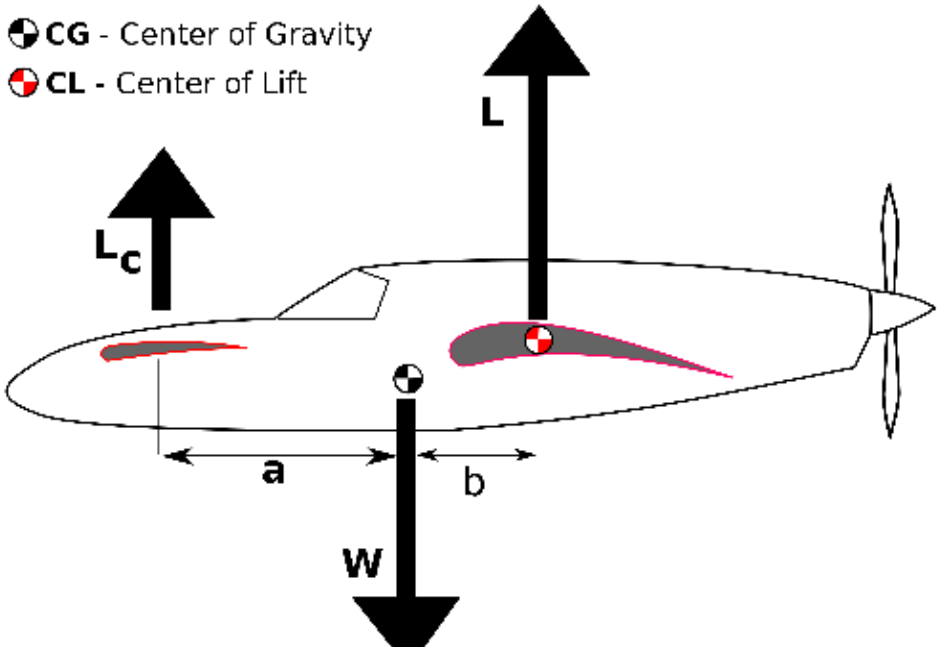


(a) Main Wing Forward with Control Surface



- This is accepted as the conventional arrangement and is by far the most ubiquitous.
- The aircraft centre of mass is forward of the wing centre of lift and this is balanced by a download on the tailplane, thus providing aerodynamic speed and attitude stability in the horizontal plane
- A vertical fin provides weathercock stability in yaw.

(b) Canard Configuration

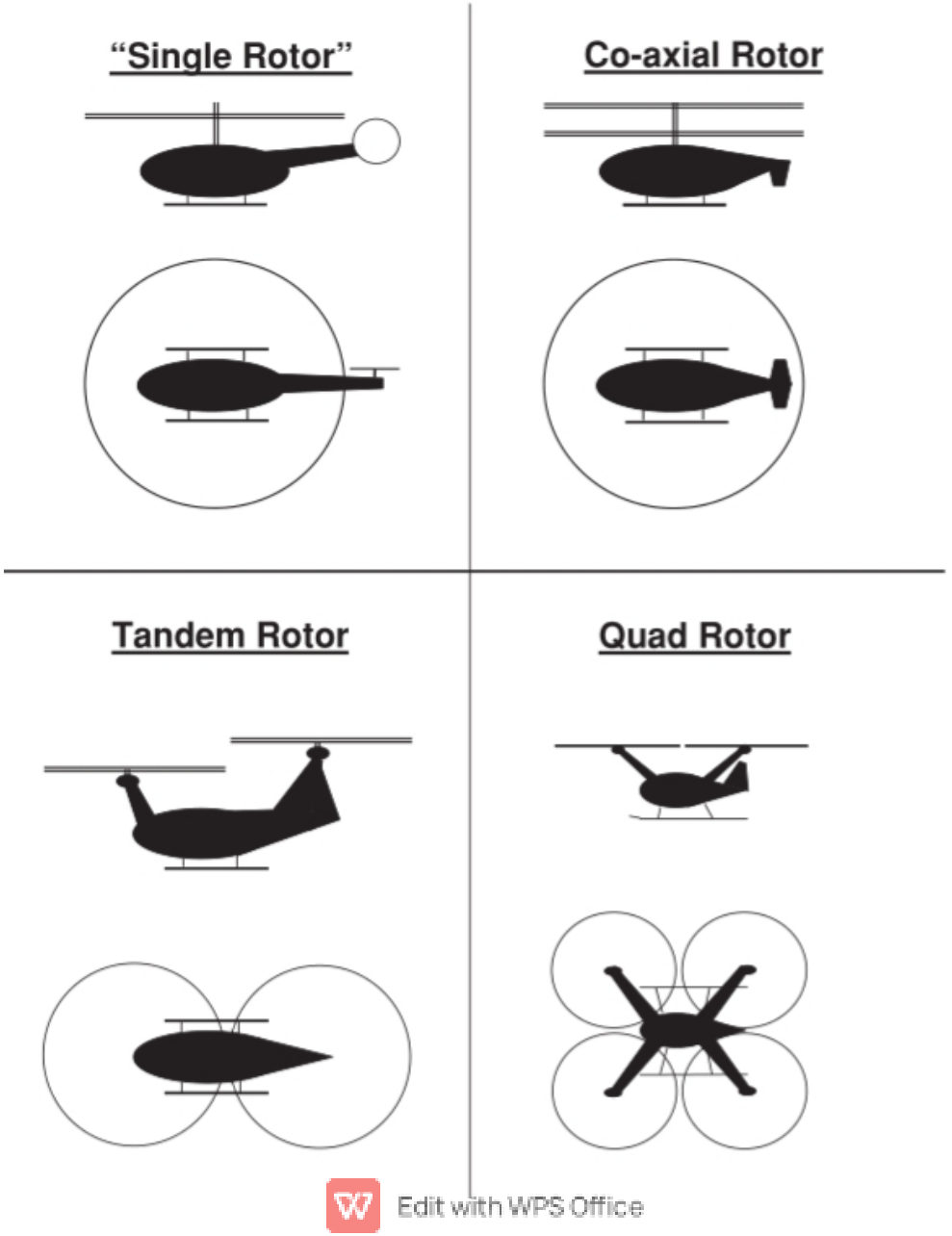


- A canard configuration has the horizontal stabiliser, or foreplane, mounted forward of the wing.
- The aircraft centre of mass is also forward of the wing and the balance is achieved with the foreplane generating positive lift.
- An advantage of the canard system is that as both planes are generating positive lift, it is aerodynamically more efficient than the tail-aft configuration
- disadvantage of the canard is that directional stability is less readily achievable since, as the aircraft centre of mass is more rearward, the tail fin (or fins) do not have the leverage that the tail-aft arrangement has.

c) Flying Wing or “Tailless Configurations

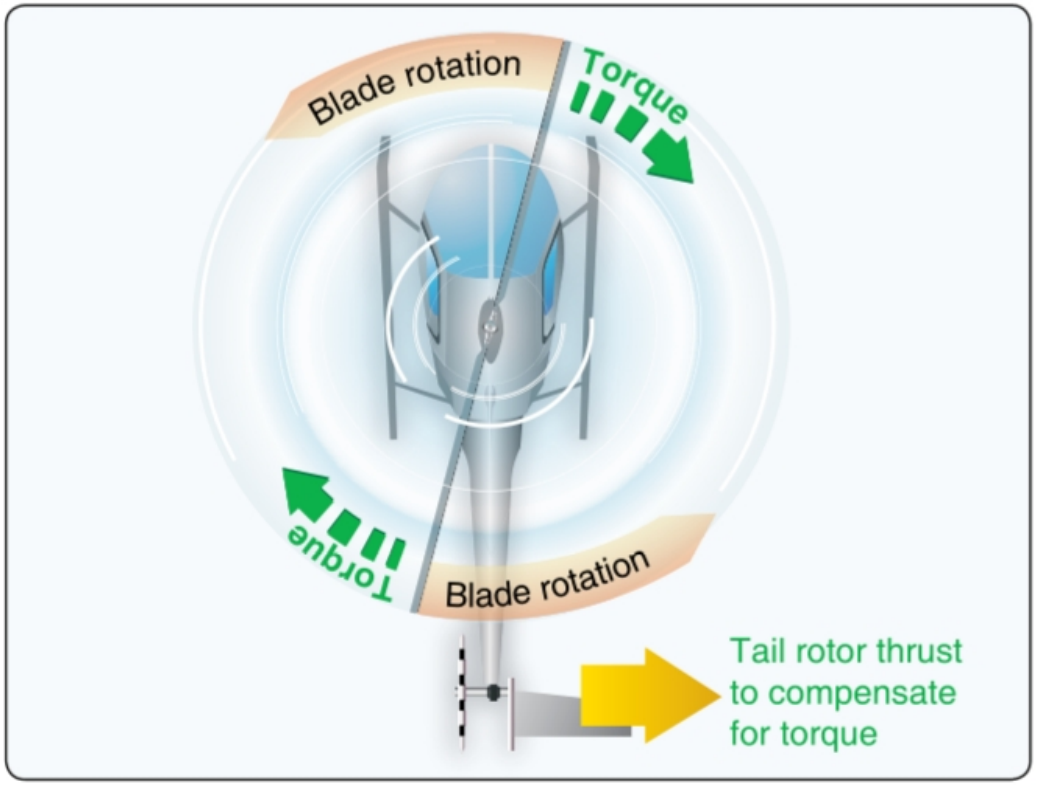
- This includes delta-wing aircraft which, as with the above, have an effective ‘tail’.
- The wings have a ‘sweep-back’ This ensures that, as the aircraft nose rises, the centre of lift of the wing moves rearwards, thus returning the aircraft to its original attitude

2) VTOL or vertical take-off and landing:



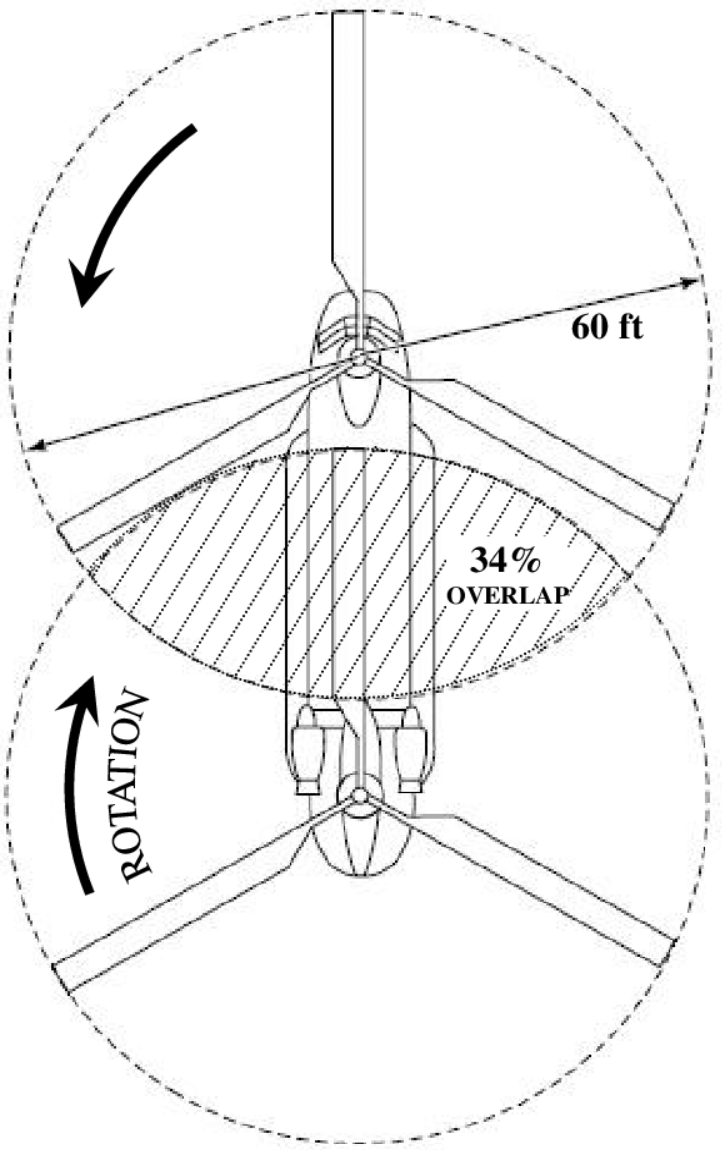
(a) Single-main-rotor

- Here the torque of the main rotor, which tends to turn the aircraft body in the opposite rotational direction to the rotor, is counteracted by a smaller, side-thrusting, tail rotor which typically adds about a further 10% onto the main rotor power demands.
- Single Main rotor provides both lift and thrust.
- a disadvantage is that the aircraft is extremely asymmetric in all planes which adds to the complication of control and complexity of the algorithms of the flight control system



(b) Tandem Rotor

- it is more efficient to fit two smaller rotors one behind other than one large one to aircraft with more weight
- Here the rotors rotate in opposite manner(front rotor in anticlockwise direction and rear rotor in clockwise direction)



c) Coaxial Rotor

Coaxial rotors or coax rotors are a pair of helicopter rotors mounted one above the other on concentric shafts, with the same axis of rotation, but turning in opposite directions.

It is not more generally popular due to its greater height compared with that of the other configurations.

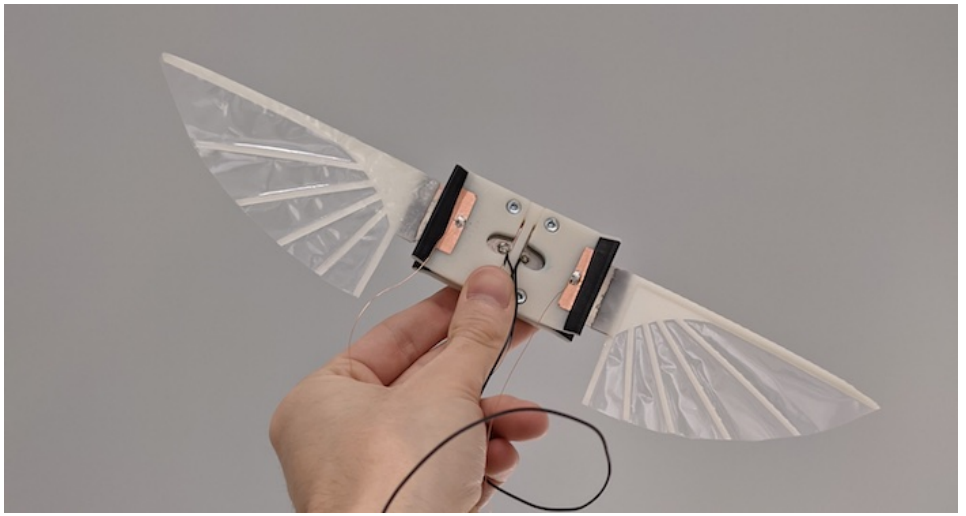
The advantages of the configuration include an almost perfect aerodynamic symmetry, compactness with no vulnerable tail-rotor

It can present disadvantages in maintenance and in hangarage

d)multirotor

- A quadcopter is a multirotor drone with four arms or booms, each with a rotor (hence “quad copter”). Multirotor drones are unmanned aerial vehicles (UAV) with multiple rotors that are used to generate lift to enable the aircraft to fly.
- The working principle is that one pair of rotors turns clockwise and the other anti-clockwise, and by varying the speeds it is possible to generate thrust as well as turning motions.

3)Flapping wing aircraft



- The ornithopter or “flapping wing” utilizes bird flying mechanics as the power source of the UAV. This technology has been used by the military to develop a small “bird-like” UAV capable of surveillance.

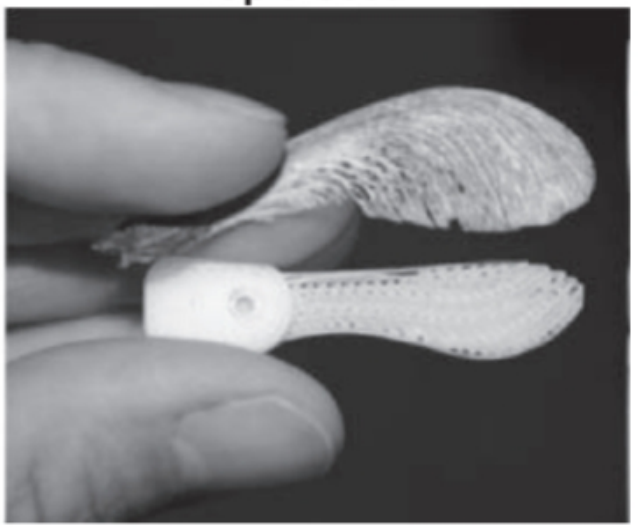
Based on size

1)Very Small UAVs

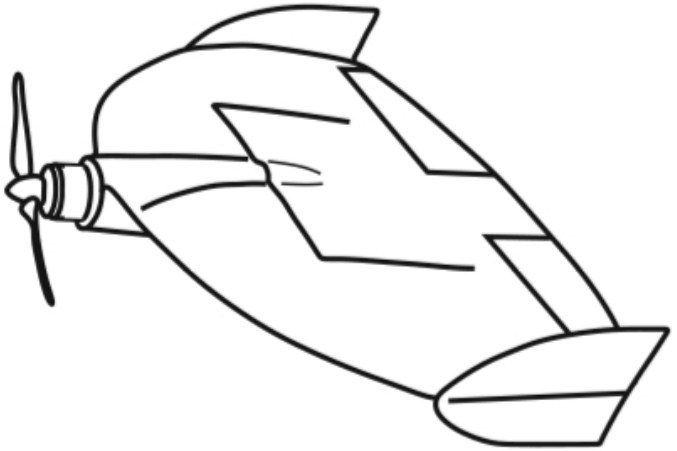
Prox-Dynamics "Pico-flyer"

Rotor Diameter	60mm
AUM	3.3gm
Battery	1 x 3.7V, 30mAh
Camera System	?
Flight Endurance	1 min
Radio Link	900 MHz
Forward speed	10m/s?

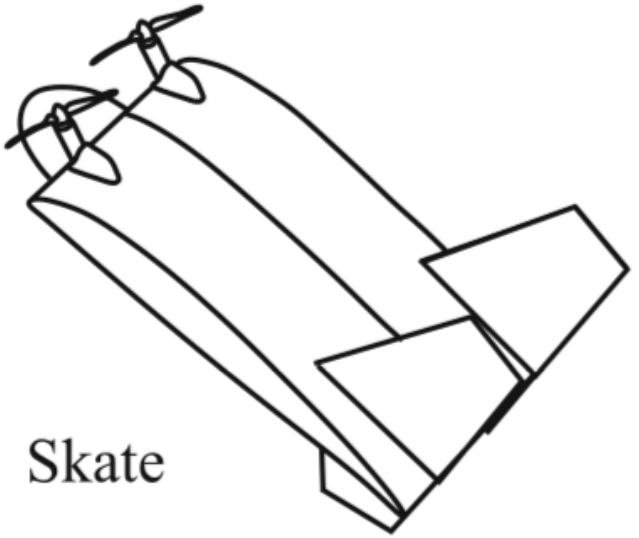
Lockheed-Martin / DARPA "Maple-Seed"



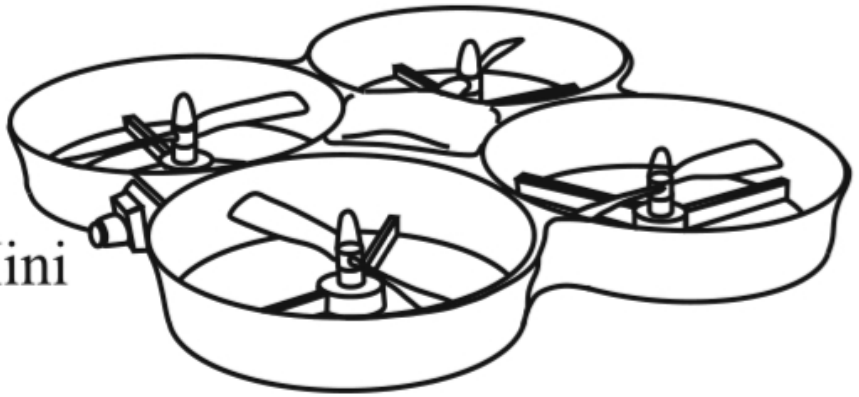
Objectives:-	
Flight Endurance	2 min.
Camera mass	2g
Forward speed	10m/s
Power	Solid rocket in tip
Cost	<20$



Mosquito



Skate

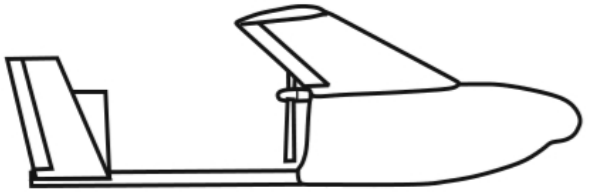


CyberQuad Mini

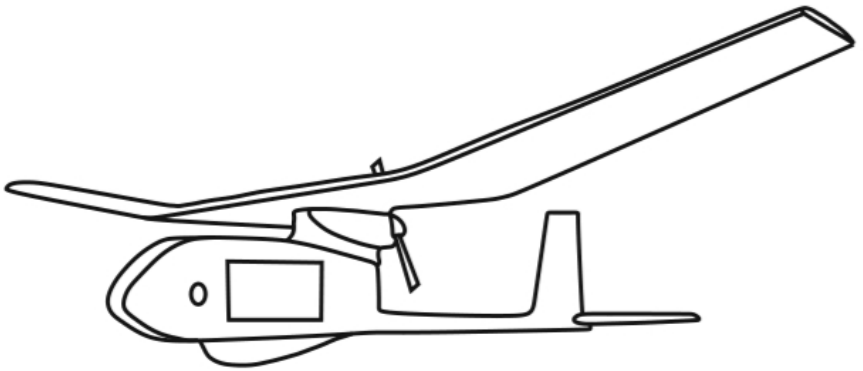
- very small UAVs” range from “micro” sized, which are about the size of a large insect up to an AV with dimensions of the order of a 30–50 cm (12–20 in.).
- There are two major types of small UAVs. One type uses flapping wings to fly like an insect or a bird and the other uses a more or less conventional aircraft configuration, usually rotary wing for the micro size range.

2)Small UAVs

- “small UAVs” have at least one dimension of greater than 50 cm (19.7 in.) and go up to dimensions of a meter or two.
- Many of these UAVs have the configuration of a fixed-wing model airplane and are hand-launched by their operator by throwing them into the air much as we launch a toy glider.



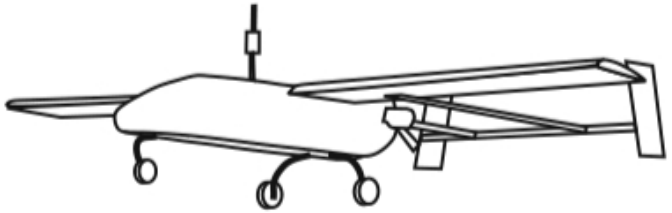
Bayraktar



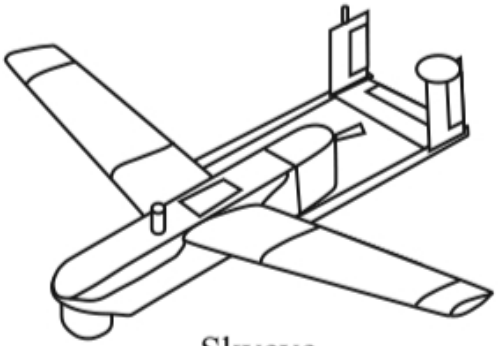
Raven B

3)Medium UAVs

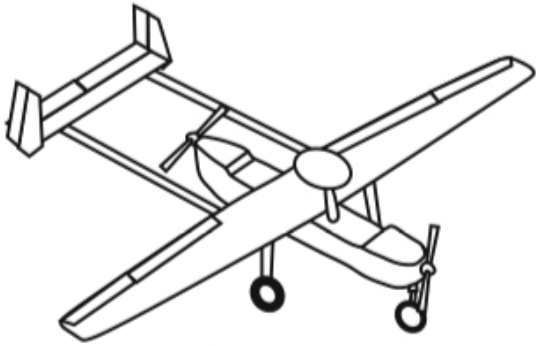
- They have typical wingspans of the order of 5–10 m (16–32 ft) and carry payloads of from 100 to more than 200 kg (220–440 lb). There are a large number of UAVs that fall into this size group.
- There are also a large number of rotary-wing UAVs in this size class. A series of conventional helicopter with rotor diameters of the order of 2 m (6.4 ft)



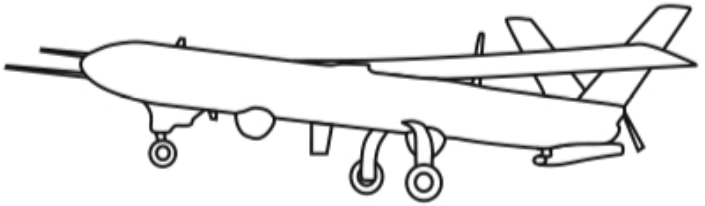
Pioneer



Skyeye

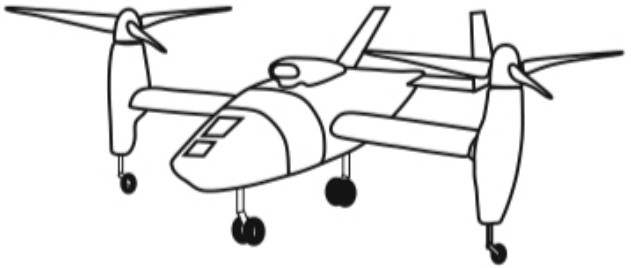


Hunter



Watchkeeper

Fire Scout

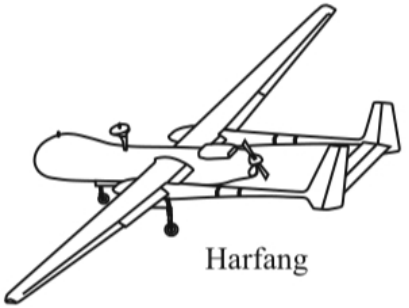


Eagle Eye

4)Large UAVs

- This includes, in particular, a group of UAVs that can fly long distances from their bases, loiter for extended periods to perform surveillance functions. They also are large enough to carry weapons in significant quantities

Predator A



Harfang

Global Hawk

Classification by Range and Endurance

1)HALE – High altitude long endurance.

- Over 15 000 m altitude and 24+ hr endurance.
- They carry out extremely long-range (trans-global) reconnaissance and surveillance and increasingly are being armed. They are usually operated by Air Forces from fixed bases.

2)MALE – Medium altitude long endurance.

- 5000–15 000 m altitude and 24 hr endurance.
- Their roles are similar to the HALE systems but generally operate at somewhat shorter ranges, but still in excess of 500 km. and from fixed bases.

3)TUAV – Medium Range or Tactical UAV with range of order. between 100 and 300 km.

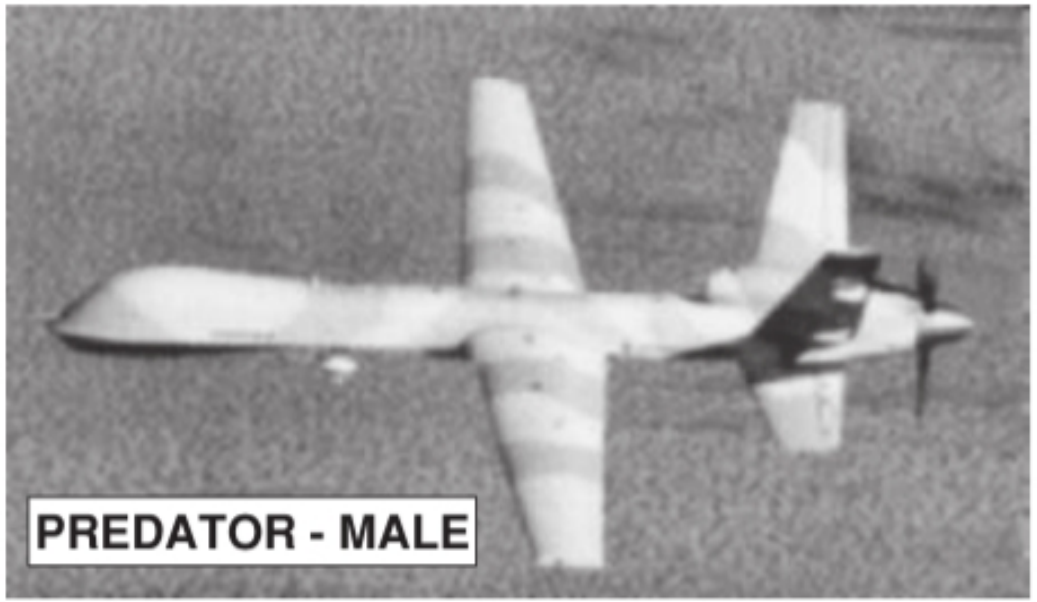
These air vehicles are smaller and operated within simpler systems than are HALE or MALE and are operated also by land and naval forces

GLOBAL HAWK – HALE

Global Hawk Block 20 (Tier 2 Plus) by Northrop-Grumman.

Wing-span	39.9m
Length	14.5m
MTOM	14,628kg
Max. Endurance	35hr
Max Altitude	19,800m
Payload - mass	1,360kg

Stabilised, high-magnification
Optical and I.R. TV.
Synthetic Aperture Radar



PREDATOR - MALE

Predator B by General Atomics Inc.

Wing-span		20m
Length		10.6m
MTOM		4,536kg
Max. Endurance		32hr
Ceiling		12,000m
Payload :-	mass	230kg

Stabilised, High-mag.
Optical and I.R. TV.
S.A.R.

Applications of UAS

Civilian uses	
Aerial photography	Film, video, still, etc.
Agriculture	Crop monitoring and spraying; herd monitoring and driving
Coastguard	Search and rescue, coastline and sea-lane monitoring
Conservation	Pollution and land monitoring
Customs and Excise	Surveillance for illegal imports
Electricity companies	Powerline inspection
Fire Services and Forestry	Fire detection, incident control
Fisheries	Fisheries protection
Gas and oil supply companies	Land survey and pipeline security
Information services	News information and pictures, feature pictures, e.g. wildlife
Lifeboat Institutions	Incident investigation, guidance and control
Local Authorities	Survey, disaster control
Meteorological services	Sampling and analysis of atmosphere for forecasting, etc.
Traffic agencies	Monitoring and control of road traffic
Oil companies	Pipeline security
Ordnance Survey	Aerial photography for mapping
Police Authorities	Search for missing persons, security and incident surveillance
Rivers Authorities	Water course and level monitoring, flood and pollution control
Survey organisations	Geographical, geological and archaeological survey
Water Boards	Reservoir and pipeline monitoring

Military roles

Navy

Shadowing enemy fleets

Decoying missiles by the emission of artificial signatures

Electronic intelligence

Relaying radio signals

Protection of ports from offshore attack

Placement and monitoring of sonar buoys and possibly other forms of anti-submarine warfare

Army

Reconnaissance

Surveillance of enemy activity

Monitoring of nuclear, biological or chemical (NBC) contamination

Electronic intelligence

Target designation and monitoring

Location and destruction of land mines

Air Force

Long-range, high-altitude surveillance

Radar system jamming and destruction

Electronic intelligence

Airfield base security

Airfield damage assessment

Elimination of unexploded bombs

India and Drones

- The UAV fleet of the Indian armed forces predominantly consists of the searcher, Heron2 and Harop UAV, which are imported from Israel.
- India’s indigenous UAVs are still in the development phase
- Its indigenous target drone and UAV development programme is led by the Aeronautical Development Agency (ADA) of the Defence Research and Development Organisation (DRDO), which is primarily directed towards meeting the requirements of the Indian armed forces.
- India has developed target drones and micro and mini UAVs and is aspiring to developbigger and more capable Medium Altitude Long Endurance (MALE), High Altitude Long Endurance (HALE) and armed UAVs and Unmanned Combat Aerial Vehicles (UCAVs) indigenously

Some of the Indian Drones are:

1. **Aura** : AURA is an autonomous stealthy unmanned combat air vehicle (UCAV) developed by the DRDO for the Indian Air Force.

* The design work on the UCAV is to be carried out by the Aeronautical Development Agency (ADA).

* The UCAV will be capable of releasing missiles, bombs and precision-guided munitions.

2.**Imperial Eagle** : EAGLE is an Indian light-weight mini-unmanned aerial vehicle (UAV) developed by the DRDO alongside Aeronautical Development Establishment, and the National Aerospace Laboratories and supported by private vendors.

* Its primary users will be the National Security Guard and the military services.

* The Imperial Eagle weighs 2.5 kg and can carry either a daylight camera or thermal night vision camera.

* Designed to be carried in soldier's backpack, be hand-launched and recoverable through a soft landing.

*The primary advantage of the vehicle is that it functions on autopilot.

*Its orientation can be controlled using a dedicated real-time operating system (RTOS).

3. **Netra** : The Netra is an Indian, light-weight, autonomous UAV for surveillance and reconnaissance operations.

* The DRDO Research and Development Establishment (R&DE), and Idea Forge, a Mumbai-based private firm developed Netra.

* Netra can also is launched from a small clearing, and it can fly up to a distance of 2.5 km from its take-off point.

* It can carry out surveillance in an area of 1.5 km Line of Sight (LOS) at the height of 300 m, for 30 minutes on a single battery charge.

* It has a high-resolution camera with zoom to facilitate more comprehensive surveillance and can also carry a thermal camera for night operations.

4. **Rustom** : It is a Medium Altitude Long Endurance uncrewed air vehicle (UAV) developed by DRDO for the Armed forces.

* Rustom has three variants like Rustom-I, Rustom-H, Rustom-II.

* Payload capacity of 95 kgs and have a length around 5.12m.

* Rustom-II can attain max speed up to 150kmps and operated along LOS.

Nishant : It is an Unmanned Aerial Vehicle (UAV) developed by India's ADE (Aeronautical Development Establishment), a branch of DRDO for the Indian Armed Forces.

* The Nishant UAV is primarily tasked with intelligence gathering over enemy territory and also for reconnaissance, training, surveillance, target designation, artillery fire correction, damage assessment.

* The UAV has an endurance of four hours and thirty minutes.

* The 380 kg Nishant UAV requires rail-launching from a hydro-pneumatic launcher and recovered by a parachute system.

* Nishant is one of the few UAVs in the world in its weight-class capable of being catapult-launched and recovered by using a parachute * This eliminates the need for a runway as in case of the conventional take-off and landing with wheels.

AURA

IMPERIAL EAGLE

NETRA

RUSTOM

NISHANT