Basic Concepts of UAV

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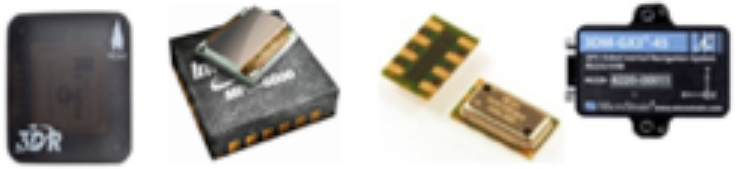
Supported by NSF DGE-1956193



Flight Computer, Avionics and Power Supply System.

Mounting System (Gimbal + Control)

Ranging System (LIDAR and LRF)

Vision System (mono & stereo)

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Airframes: Quad/Multirotors

- Except for tri-copters, multirotors use an equal number of fixed mount CW and CCW motors.
  - tricopters use 2 fixed rotors plus 1 tiltable
  - 6 degrees of freedom: 3 rotational, 3 translational
  - lift, tilt, rotation are controlled by varying speed of motors

Fixed Wing and Rotary Wing

- Fixed-wing uses a wing like a normal aeroplane to provide the lift rather than vertical lift rotors.

- Rotary-wing uses lift created by rotary wings (rotor blades) that revolve around a mast.

Autopilot

- The "brain" of the UAV (drone).
- It consists of flight stack software running on vehicle controller ("flight controller") hardware.
- Flight stack software: e.g., PX4 Autopilot, ArduPilot
- Flight controller: e.g., Pixhawk, DJI Naza

Sensors

- UAVs use sensors to determine vehicle state
  - position/altitude, heading, speed, airspeed, orientation (attitude), rates of rotation in different directions, battery level, etc.

- The system *minimally requires*
  - Gyroscope: measure or maintain the orientation and angular velocity
  - Accelerometer: measures proper acceleration
  - Magnetometer (compass)
  - Barometer: measure air pressure in a certain environment.

- A GPS or other positioning system is needed to enable all automatic modes and some assisted modes.

- Airspeed sensor is needed for fixed wing and VTOL UAVs.

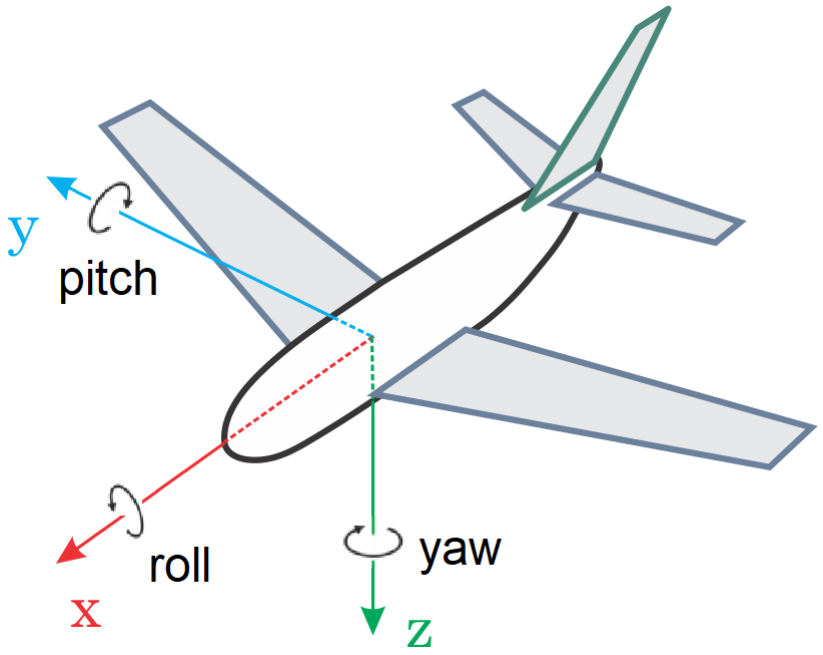
GPS & Compass

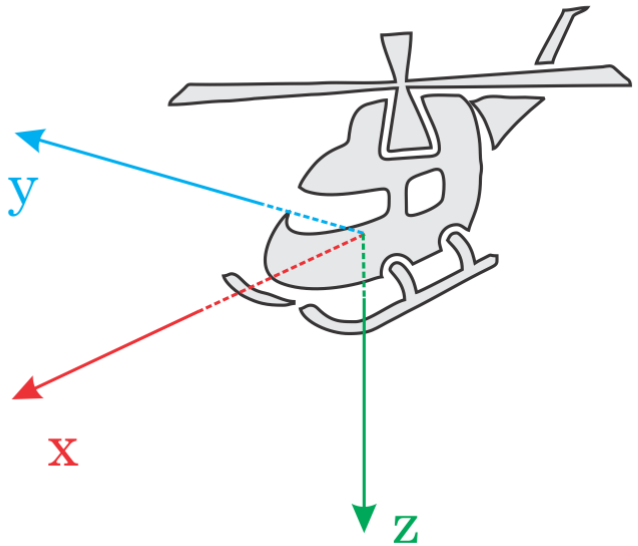
- The Global Positioning System (GPS) is a navigation system using satellites, a receiver and algorithms to synchronize location, velocity and time data.

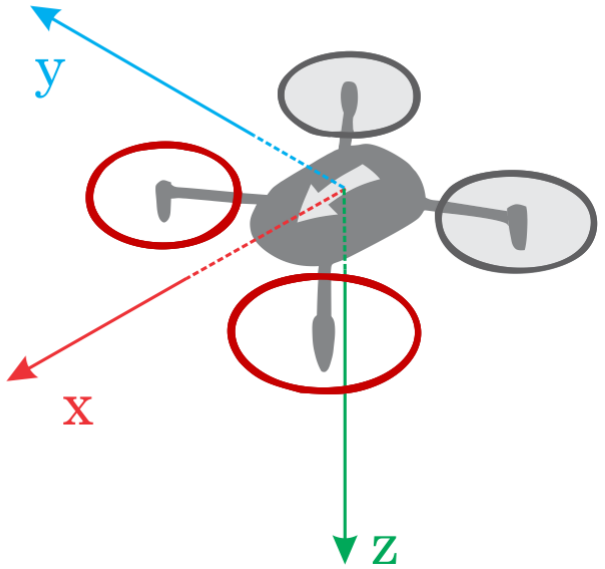
- The purpose of a compass is to work together with the GPS and help determine direction.

Heading and Directions

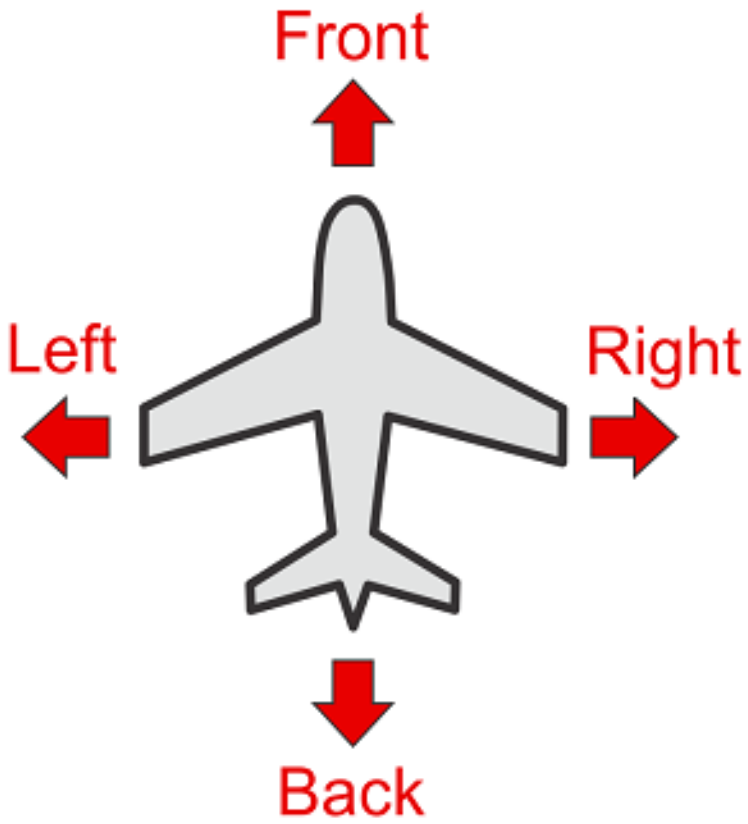
All the vehicles, boats and aircraft have a heading direction or an orientation based on their forward motion.

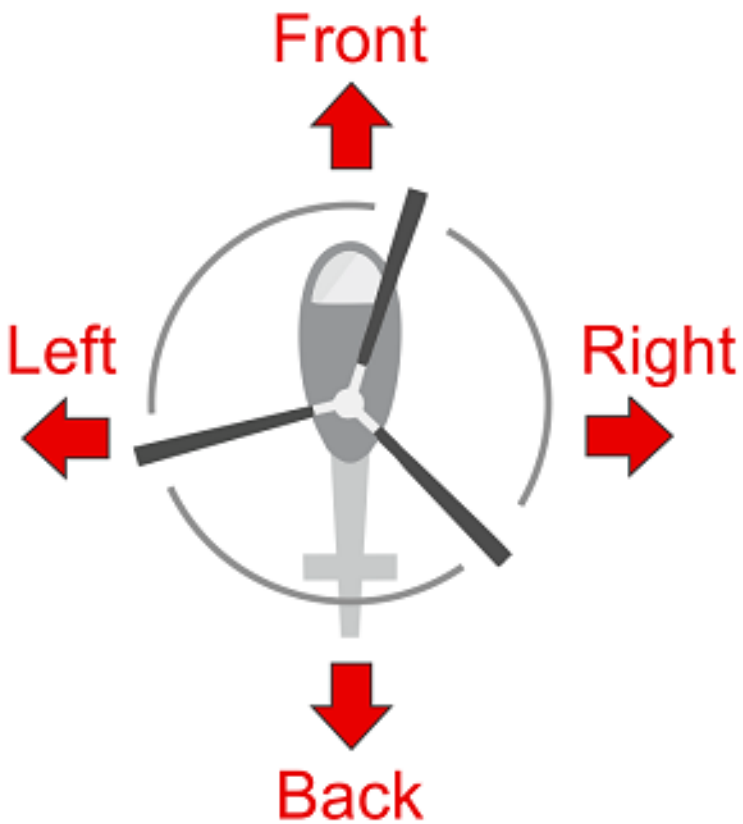


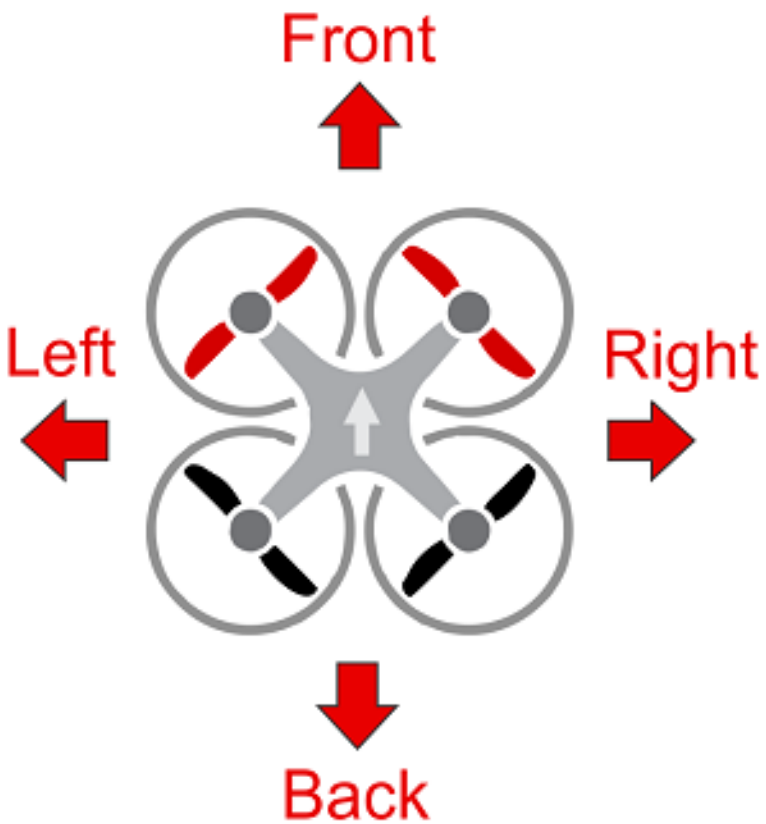




Heading and Directions



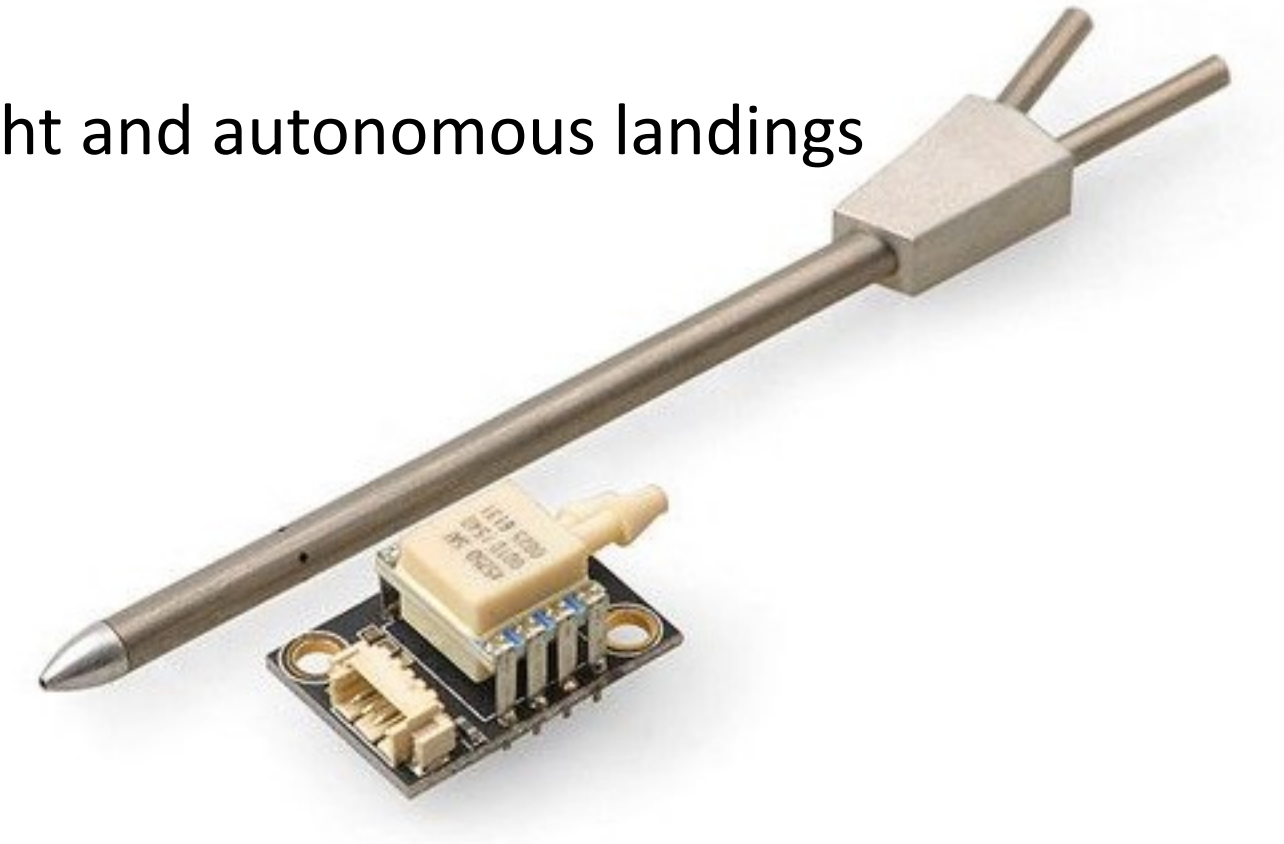




Airspeed

- A flight instrument indicating the airspeed of an aircraft and detect stall.

- Help in windy conditions, slow flight and autonomous landings



Distance Sensors

- Distance sensors provide distance measurement that can be used for terrain following, terrain holding (i.e. precision hovering for photography), improved landing behaviour (range aid), warning of regulatory height limits, collision prevention, etc.

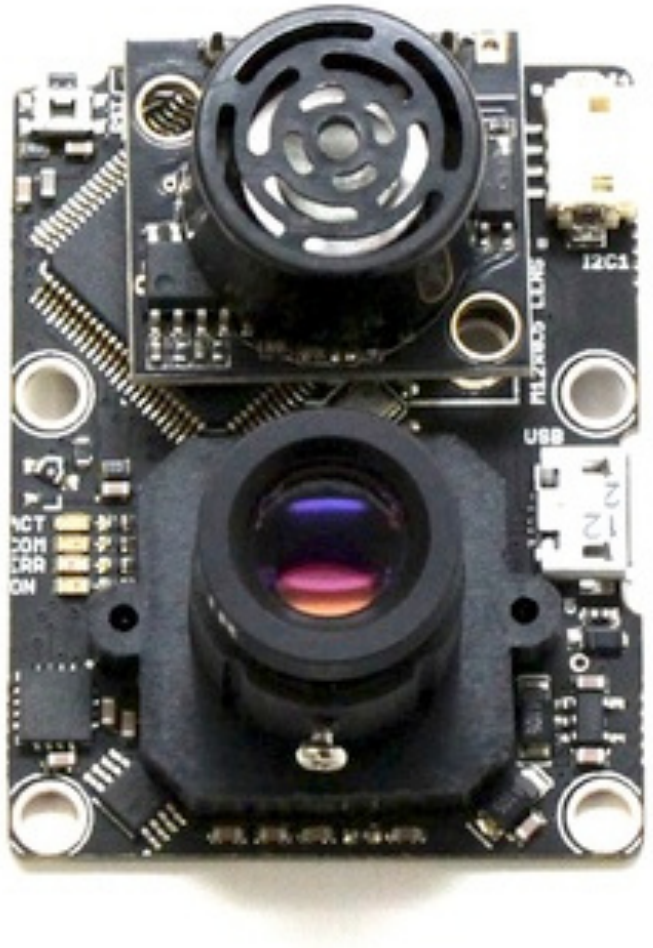
  - Radar Altimeter: measure altitude above the terrain presently beneath an aircraft or spacecraft by timing how long it takes a beam of radio waves to travel to ground, reflect, and return to the craft.

  - Lidar: measure distances by illuminating the target with laser light and measuring the reflection with a sensor.

Optical Flow Sensors

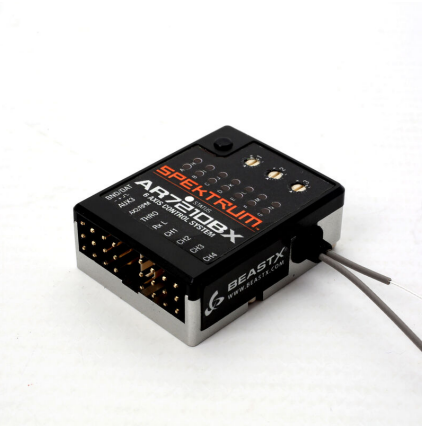
- A downward facing camera and a downward facing distance sensor for velocity estimation.

- Sensor output can be blended with information from other position sources (e.g. GPS) to provide a more accurate position lock.



Radio Control Systems

- A Radio Control (RC) system is used to manually control the vehicle.
- It consists of a remote control unit that uses a transmitter to communicate stick/control positions with a receiver based on the vehicle.
- The remote has physical controls that can be used to specify vehicle movement (e.g. speed, direction, throttle, yaw, pitch, roll, etc.) and to enable autopilot flight modes (e.g. takeoff, land, return to land, mission etc.)
- The remote control unit contains a radio module that is bound to, and communicates with, a (compatible) radio module on the vehicle.



Radio Control Systems

- An important quality of an RC system is how many "channels" it supports.

- The number of channels defines how many different physical controls on the remote control can be used to send commands to the vehicle (e.g. how many switches, dials, control sticks can actually be used).

- An aircraft must use a system that supports at least 4 channels (for roll, pitch, yaw, thrust).

Data/Telemetry Radios

- Data/Telemetry Radios can provide a wireless MAVLink connection between a ground control station and the UAV.

- This makes it possible to tune parameters while a vehicle is in flight, inspect telemetry in real-time, change a mission on the fly, etc.

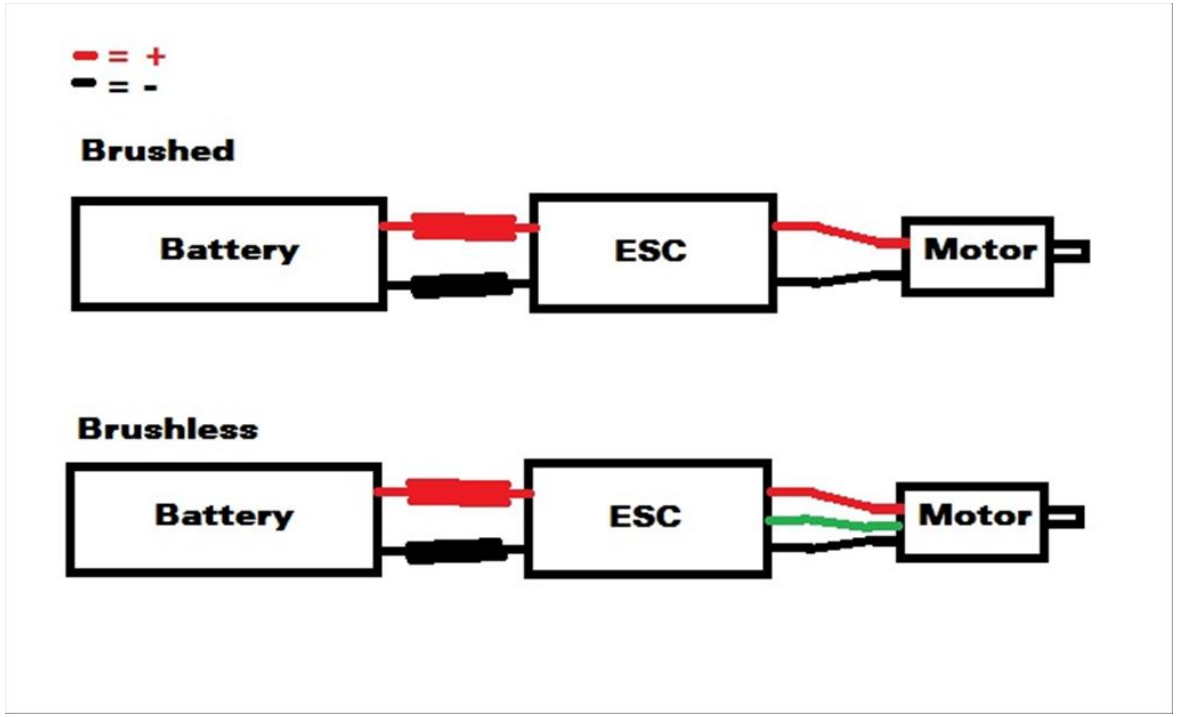
Offboard/Companion Computer

- UAV can also be controlled from a separate on-vehicle companion computer via a serial cable or wifi.

- The companion computer will usually communicate using a MAVLink API like the MAVSDK or MAVROS.

ESCs & Motors

- UAVs use brushless motors that are driven by the flight controller via an Electronic Speed Controller (ESC).
- The ESC converts a signal from the flight controller to an appropriate level of power delivered to the motor.



Battery/Power

- Drones are mostly commonly powered from Lithium-Polymer (LiPo) batteries.

- The battery is typically connected to the system using a Power Module or Power Management Board, which provide separate power for the flight controller and to the ESCs (for the motors).