Drones:

A drone, in technological terms, is an unmanned aircraft. Drones are more formally known as unmanned aerial vehicles (UAVs) or unmanned aircraft systems (UASes). Essentially, a drone is a flying robot that can be remotely controlled or fly autonomously through software-controlled flight plans in their embedded systems, working in conjunction with onboard sensors and GPS.

In the recent past, UAVs were most often associated with the military, where they were used initially for anti-aircraft target practice, intelligence gathering and then, more controversially, as weapons platforms. Drones are now also used in a wide range of civilian roles ranging from search and rescue, surveillance, traffic monitoring, weather monitoring and firefighting, to personal drones and business drone-based photography, as well as videography, agriculture and even delivery services.

How Drones Work:

While drones serve a variety of purposes, such as recreational, photography, commercial and military, their two basic functions are flight and navigation.To achieve flight, drones consist of a power source, such as battery or fuel, rotors, propellers and a frame. The frame of a drone is typically made of lightweight, composite materials, to reduce weight and increase maneuverability during flight.Drones require a controller, which is used remotely by an operator to launch, navigate and land it. Controllers communicate with the drone using radio waves, including Wi-Fi.

Drone Parts:

Mechanical and Chemical Parts	+ Hardware or Software Required Parts	
Frame	ESC	Power Management Unit
Motor	Flight Controller	Video Transmitter
Propeller	IMU & Magnetometer	Antennas
Battery	Remote Control Receiver	Buzzer
	Telemetry Unit	Camera Unit - Camera - Gimbal - OSD
	GPS / GNSS	

Frame:

Frame -The structure that holds all the components together. One of the most important part of quadcopter is its frame because it supports motors and other electronics and prevents them from vibrations. You have to be very precise while making it. They need to be designed to be strong but also lightweight.

Materials for Quadcopter Frame:

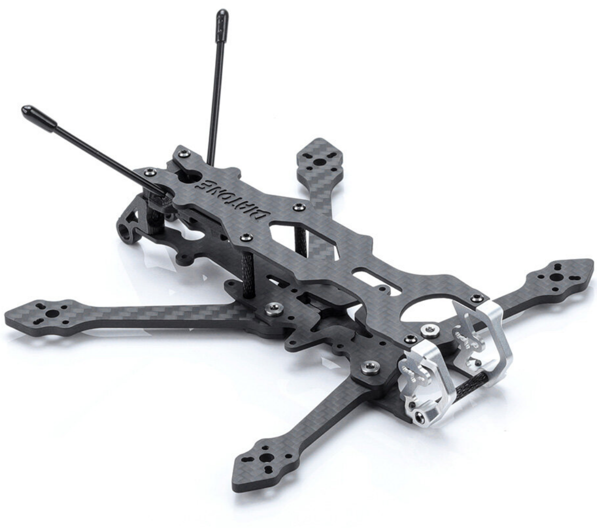
Carbon Fiber: One of the most common materials for multi-rotor frames is carbon fiber.It is lightweight but expensive. A great many of its physical properties are perfectly suited to the hobby. The only catch is that carbon fiber is known to block radio signals, which is obviously not ideal for a hobby that depends on multiple transmissions. That means you have to exercise a bit of care in how you place antennas on your craft. It can be used though, and is often. Just be aware that blocked signals are a possibility

Wood: Build a frame with wood, It's fast, low cost and does not require much effort. While not nearly as sexy as carbon fiber or fiberglass, is a very good material for this sort of thing. It’s cheap, RF transparent, takes brief structural overloads well, uses simple adhesives and dampens vibrations wonderfully.

Aluminium: it is widely used for frame, you need to buy parts and have some tools to cut or connect them together. Very lightweight and aluminum can transmit vibration quite well. Aluminum is easy to fabricate and can often be bent back into shape after crashes.

Plastic & PVC: Frame usually be 3D printed with plastic, This material is lightweight, cheap, and perhaps a bit to ugly for your new quadcopter frame as well as PVC.

Fiberglass: Another material you could consider is thin G-10 fiberglass sheet which is easily machinable. This is nice for the body area as it's RF transparent. It also makes nice motor mounts.
Although it is not as important as for the arms which of the three material to use for the center plate, Carbon Fiber and plywood are most commonly seen because of its the light weight, easy to work with and good vibration absorbing features.



Electromagnetism:

Electric motors of both types, brushed and brushless, use the same principles of electromagnetism to convert electrical energy into rotation. If a voltage is applied to a copper wire, a current will flow, which will induce a magnetic field. With a permanent magnet near this current-carrying copper wire it is possible to generate linear or rotational forces to the wire and the magnet.

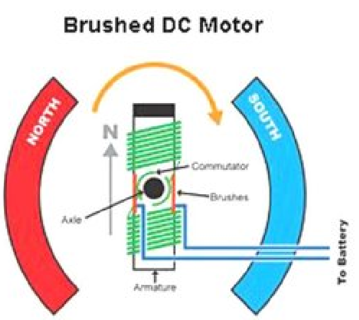
Brushed DC Electric Motor:

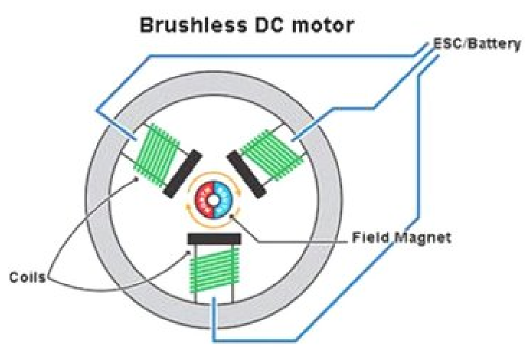
Some years ago brushed motors were used in rc plane models, which have a big disadvantage. As the name suggests, brushed dc motors require carbon brushes, which make contact to the rotating rotor to enable the flow of current. The brushes of a dc motor are made of graphite which is a wearing part that reduces the efficency. Another disadvantage are sparks, which can disturb or damage other electrical components. Because of the constant stress that these parts have to endure in a multicopter, they would need to be replaced often. A brushed dc motor consist of multiple parts, that act together, to create a rotation: a static part, called the stator, and a rotating part, which is the rotor. Permanent magnets with alternating polarity are attached to the stator. The rotor also known as armature, which consists of a soft iron core that is wrapped by a copper coil. A current that flows through the coils of the armature produces a magnetic field, which has a north and a south pole. The orientation of the poles is in accordance to the direction of the current. To achieve a rotation of the rotor the magnetic orientation of the current-carrying coil has to be directed, such that the repulsion and attraction of the magnetic fields between stator and rotor generate a permanent rotation. The problem is to keep the rotation by changing the poles of the copper coils - commutate. To achieve this a commutator is used. During the rotation of the rotor, its purpose is to switch (commutate) the direction of current flow and therefore to change the direction of the magnetic field. This makes the commutator an electrical switch. The current has to be transfered of a static part onto the rotating commutator, where the previously mentioned brushes are used. These are made of graphite and are in light contact with the commutator through a spring.

Brushless DC Electric Motor:

As the name suggests, brushless dc motors require no wearing brushes for their construction. The commutation occurs electrically, not mechanically. In this case commutation is the interchange of the current through the coils to make the motor spin. The reason that no brushes are necessary for the flow of current, is that the change in direction of the current is happening on the stator. Therefore the current doesn't have to be transfered to the rotating rotor, which aleviates the wearing parts - the brushes and the commutator. The current-carrying copper coils are wound around the stator sleeve. Attached to the rotor bell are permanent magnets in alternating polarity, which are often made of neodymium. Operating principle of a Brushed DC Motor. Neodymium is a chemical element in the periodic system with the symbol Nd and atomic number 60. It belongs to the lanthanide series and is a rare-earth element. Magnets manufactured from this element, count to the strongest magnets on earth. For a brushless dc motor to work, it requires three phase wires instead of two in the case of a brushed dc motor. The three phases carry AC current where each phase is shifted by 120 degrees. This way the current direction and therefore the direction of magnetic fields are changed, which leads to repulsion and attraction with the permanent magnets that are attached to the rotor.

brushless motor





Propeller:

Drones requires propellers to translate the stored energy of the battery into kinematic energy. The structure of propellers are comparable to the wings of an airplane, which provides uplift when moving forward and lifts the plane off the ground. The propeller causes a similar effect with the difference that not the whole plane needs to move forward. Instead, the uplift is created through the rotation of the propeller similar to a helicopter.

Plastic, Fiberglass or Carbon:

SPropellers can consisto of different materials. Small and in general inexpensive propellers are made of conventional plastic (e.g. EPP propellers). Improve quality of propellers is achieved through addition of carbon fiber or fiberglass. Propeller materials mixed of carbon- and fiberglass exist too. The best quality comes with a propeller consisting of pure carbon fiber because they are very light and highly efficient. Because of its expensive material and manufacturing process it is more expensive compared to a traditional plastic propeller.

LiPo and LiHV Drone Battery:

The lithium battery packs used to power quadcopters have two common chemistries: Lithium polymer (LiPO) and lithium polymer high voltage (LiHV). The primary difference between the two is that a LiPO cell has a fully charged voltage of 4.2V compared to a LiHV cell which has a voltage of 4.35V at full charge. A LiPO has a resting or nominal voltage of 3.7V versus a LiHV which has a storage voltage of 3.8V. In regards to the performance of the two packs, a LiHV battery will initially provide more power but abruptly drops in voltage when discharged whereas a LiPO has a more linear discharge making it easier to qualitatively gauge the remaining flight time.

Battery Cells and Voltages:

Battery voltage is the potential energy difference between the positive and negative terminals. A higher battery voltage allows the pack to provide more power to the quadcopter without increasing the current or amp draw. A standard lithium polymer cell has a nominal (storage) voltage of 3.7V hence to increase the power that a single LiPO pack can deliver, these cells are grouped together in series (meaning the ground/negative lead from the first cell is connected to the positive lead of the next cell, forming a chain of individual cells) to increase the overall battery pack voltage. LiPO packs are commonly sold in 1S, 2S, 3S, 4S, 5S or 6S configurations where the digit followed by the ‘S’ stands for number of cells in that specific pack. The more cells that are grouped together, the more voltage the overall battery pack will have. The battery pack voltage is important as it impacts the maximum motor speed of a quadcopter. More battery voltage allows the motors to spin with greater speed (RPM). For this reason, 4S LiPO’s are the most commonly used for quadcopters as they provide a balance between speed and weight. The following table summarizes the voltage and common applications for various LiPO cell configurations. It is important to note that the quadcopter applications listed in the following table are only typical examples from the many different battery-quadcopter combinations in existence. Exotic setups such as 5S 150mm racing quadcopters or 2S micro brushed quadcopters do exist however they are just quite uncommon.

Battery Capacity:

Battery capacity is measured in milliamp hours (mAh) which is a unit describing the current a battery can supply for a unit of time. As an example, a 1500mAh battery would be able to supply: 1500 milliamps (1.5A) of current for an hour, 3000mA (3A) of current for a total of 30 minutes, 6000 mA (6A) for 15 minutes and so on. A higher milliamp rating on a battery essentially means that it will provide more flight time per charge. When choosing a battery, a sacrifice must be made between the battery size and the weight. A larger capacity battery will provide a longer flight times however the added weight will restrict the performance of the quadcopter by increasing the craft’s momentum thereby making it respond in a more sluggish manner. In racing scenarios, the usual selected battery capacities for a 220 sized quadcopter range from 1000mAh to 1500mAh with 1300mAh packs being the most common. On average, a 1300mAh 4S pack will last for about three minutes in a racing quadcopter although flight time is entirely dependent on the manner in which the craft is flown. A professional racing pilot can easily discharge a 1300mAh 4S pack in under two minutes compared to a slower flying beginner who may experience up to five minutes of flight time with a similar battery. When flying longer or faster circuits, many professional race pilots will actually switch from a 1300mAh 4S pack to a heavier 1500mAh battery to reduce the need for battery voltage management during a race. In order to achieve increased flight times(5-8 minutes), long range quadcopter pilots will use even larger batteries up to 2200mAh as flight performance is of less regard to them than flight time.

Battery C-Rating:

The C-Rating of a battery is a unit of measurement dictating how much current a battery can continuously supply for its given charge cycle. Simply put, the higher the C-Rating of a battery, the more current the pack can continuously supply. The C-Rating can be multiplied by a batteries capacity in order to calculate a packs theoretical maximum discharge current. Larger capacity batteries can usually supply more current as their internal electrodes have a greater surface area. For example, using the below C-Rating and milliamp conversion formulae, a 1800mAh 100C battery would be able to supply more current to a quadcopter than a 1300mAh 100C battery (180,000mA/180A maximum current versus 130,000mA/130A maximum current respectively). If a battery is forced to supply more current than dictated by its C-Rating for a significant period of time, it can damage the battery by causing the cells to puff, reduce overall longevity, cause excess heating and occasionally cause a LiPO fire. For this reason, it is important to use batteries with C-Ratings that are adequate for their application. For most 220 sized quadcopters, batteries with C-Ratings of 70C or higher are usually recommended, however, quadcopters using high KV and/or large motors may require even higher C-Rating batteries.

Number of LiPO Cells	Nominal Battery Voltage	Common Quadcopter Applications
1S	3.7V	Indoor micro brushed (e.g. Tiny Whoops)
2S	7.4V	30-70mm micro brushless
3S	11.1V	100-220mm brushless
4S	14.8V	220mm brushless race/freestyle
5S	18.5V	220mm+ brushless race/freestyle/ quadcopters
6S	22.2V	220mm+ brushless

ESC Function:

Given a desired input signal from the transmitter, an ESC takes over the coordination to correctly control flow of current through the three phase wires of a brushless motor of which the currently set motor position needs to be aquired. This can be achieved through two ways: one is to use Hall effect sensors or to make use of the so called counter-electromotive force (also known as back EMF). A spinning motor also acts as a generator that generates a force which can be measured by the ESC. With this measurement the position of the rotor can be infered.

A Hall effect sensor can make use of the magnetic interaction of the magnets on the rotor to provide a signal that evaluates to the position of the rotor. A receiver or flight controller (FC) commands the the speed of a motor and compares the desired with the target speed value. With this speed difference it is possible to adjust the speed to reduce the difference.

An ESC controls the speed of a motor via pulse witdth modulation (PWM). The ESC controls the power supplied from the battery to the motor taking into account the commands of a flight controller or a receiver. For example, an ESC can be targeted to provide 50% of the maxium possible power to its connected motor. PWM controls the rate at which power is fed from the power source (battery) to the load (motor). For example, given that the PWM rate for 100% motor power is 50 kHz, an ESC which should operate the motor at 50% power will provide the full battery power at a 25 kHz rate.

Ampere (A) and Load Capacity:

ESCs control the conduction of electrical engergy from the battery to the motor. This energy throughput certainly leads to a high electrical load at the ESC. Because of this, ESCs are manufactured for different maximum load capacities, which are indicated in ampere (A). As an ESC has to fit to a selected motor, it is also important to take the maximum current the motor can pull from the ESC into account. Consider for example a motor in combination with an air blade and a specific battery voltage that requires a maximum current flow of 18 A. Such a motor cannot be controlled with an ESC that allows a maximum electrical load which is less than 18 A, for example 15 would be too less. Such a setup would damage the ESC and lead to a crashing multicopter.

To avoid this, it is important to use an ESC which can handle the maximum power consumption of the rotors and which inner build is designed for such high loads. Always make sure there is a safety buffer. A motor having a maximum current flow specification of 15 A should be operated with an ESC that can handle 20 A. For these parts it is common to see specifications that declare which maximum peak load they can handle for a short period of time.

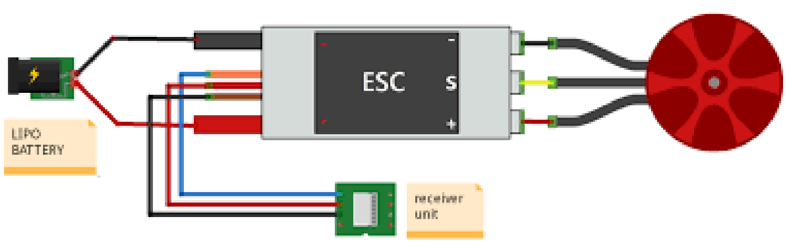
For example, a motor can handle 20 A for longer periods and 25 A for approximately 15 seconds. While choosing an ESC this has to be kept in mind. An ESC has also an extrem value. If it is specified for 25 A, it can handle up to 30 A for 15 seconds, depending on the manufacturer specifications.

Especially during FPV races, the components have to endure high loads and are at the same time chosen to operate at their limit. This enusres power and agility. ESCs with a maximum load of 20 A are installed even if the motor can pull a maximum of 20 A. For beginners, such setups are not recommended because it can lead to damaged components quickly. Instead, components should be selected with generous specifications, meaning that their limit values are not easily exceeded.

For example, when using an ESC and motor which both have their load limit at 20 A it is possible that the copter get stuck in the gras after a possible crash or the start. In such situations the motor tries, without success, to counter against the gras. After a few rotations the gras will wind around the motor which leads to increased current flow because of hight load. This value can easily increase above what is specified in the datasheet and result in a smoking ESC, even while starting.

Voltage (V) and Cell Count (S):

Another important aspect when using ESCs is that not every battery can be connected. A LiPo battery often has not only one, but two, three or even more cells. The more cells are connected in series, the higher the battery voltage. Often this is not indicated in volt but in cell count (S) of the battery. In the chapter LiPo battery the cell count is explained in more detail. It is important, that LiPo batteries are divided in cell counts from one to six (1S to 6S). However, an ESC always has a maximum operating voltage or battery cell count with that it's allowed to be operated. This means, if indicated on the ESC or its data sheet



Flight Controller:

A FPV Drone Flight Controller, or FC, is the heart of a quadcopter and controls most onboard electrical components with the assistance on an arduino-like microprocessor and an array of sensors. This article will provide information regarding the different types of FC’s and the range of possible feature integrations so that you can choose the most suitable flight controller for your application.

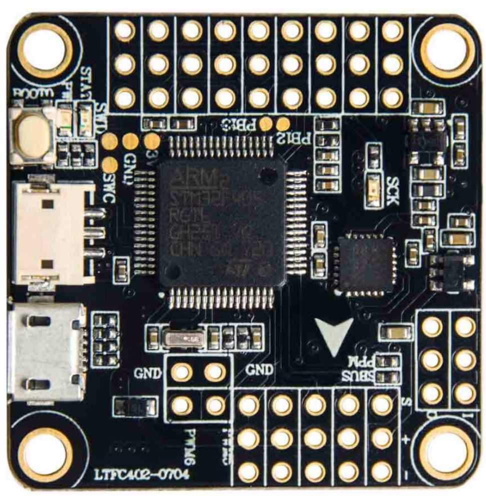
Processors:

Flight controllers are continuously evolving with their processors becoming faster to keep up with evolving flight controller softwares. Flight controllers are usually titled to include the main microprocessor’s (usually an STM electronics, 32-bit microprocessor) model as this gives the pilot a basic idea of the flight controllers capabilities. The most common microprocessor models used are the STM32 F1, F3, F4 and F7 chips. Essentially, the higher the number after the ‘F’, the faster the microprocessor will be and the more functionality it will have. For any pilot purchasing a flight controller, it is currently recommended to purchase one with an F4 or F7 processor as they are easily fast enough to run the latest FC firmwares. Unfortunately, the F1 is becoming too slow to run the latest FC firmwares and is not recommended to purchase as it will soon become unsupported. F3 boards can currently run the latest flight controller firmwares although the microprocessor is consequently slower than an F4 to F7 at reading and responding to sensor inputs. This reading and response time is respectively known as the gyro update frequency and the PID loop frequency.

Hardware:

Flight Controller is mounted to a drone frame using four equally spaced mounting holes. Currently, 30.5mm by 30.5mm spacing between hole diameters is the standard on a 220 sized quadcopter. 20mm by 20mm spacing is also quite common on 70-130 sized quadcopters. The mounting holes are usually 3mm in diameter. Smaller mounting patterns also exist although they are used almost exclusively for sub 70mm quadcopters. Many flight controllers actually use mounting holes larger than 3mm diameter to allow insertion of rubber grommets which assists in isolating the FC from motor vibration.

In regards to connecting external components to the FPV Drone Flight Controller, they can be purchased with solder pads, pin header holes, plugs, or a combination of the three. Solder pads are the most useful, compact and preferred connection as it allows neat, low profile, external componentry connections to be made. Pin header holes are also common on FC’s although, to reduce weight and connection profiles, pilots will usually solder wires directly to the holes rather than soldering on header pins and connecting wires using a servo plug. Plugs are not the most prevalent FC connection method although they allow external components to be quickly disconnected. Due to motor vibrations, thin soldered wires can eventually fray and snap off from solder pads or pin holes. To prevent this, hot gluing solder joints is a safe option to prevent loss of circuitry during flight. Solder pad FC’s are recommended for most applications however the use of connectors can also be useful for small, tight or modular setups.



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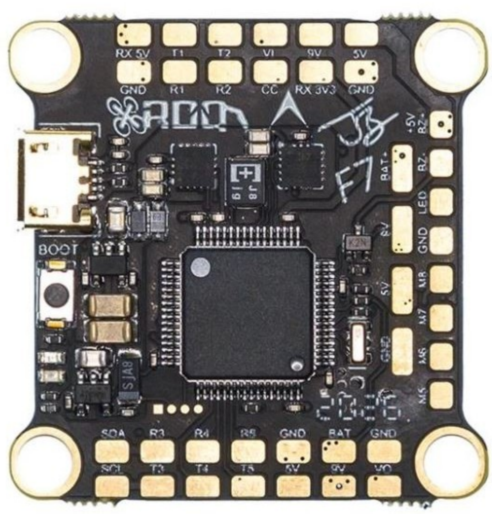


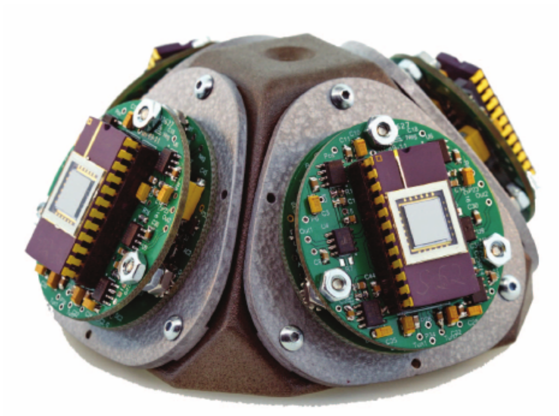
F7

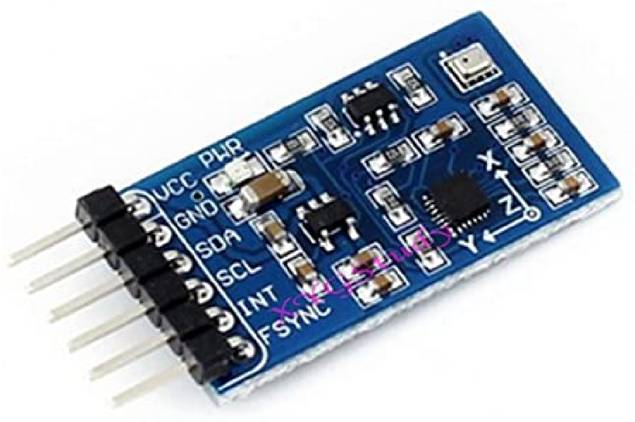
Inertial Measurement Unit:

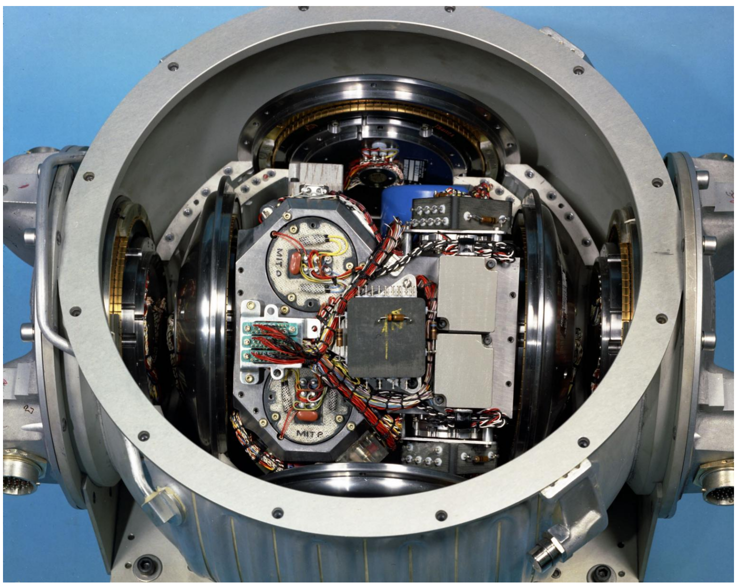
An IMU (inertial measurement unit) is a device that combines inertial sensors – gyroscopes and accelerometers – to provide acceleration and orientation data that can be used to calculate position and velocity. Some models of IMU also incorporate magnetometers, which outputs measurements of the Earth's magnetic field that can be used to improve the accuracy of orientation measurements. IMUs typically have one of each sensor per axis being measured, up to a maximum of three axes for measuring roll, pitch and yaw.

IMUs are used for a variety of applications in UAVs and drones. They allow the aircraft to maintain stability and control while experiencing high winds or performing steep turning manoeuvres. They can also be used to enable highly accurate station-keeping or autonomous waypoint following.

Inertial measurement units may be used to provide data for an AHRS (Attitude and Heading Reference System), which calculates real-time attitude and heading for manned and unmanned aircraft, or an INS (Inertial Navigation System), which calculates position in addition to orientation.







Radio Receivers:

A Radio Receiver is the device capable of receiving commands from the Radio Transmitter, interpreting the signal via the flight controller where those commands are converted into specific actions controlling the aircraft.

Radio Receivers can have the following features:
-Telemetry (sending data back to transmitter)
-Redundancy function (two receivers connected together, if one loses connection, second one takes over)
-Easy removable antennas (more convenient with connectors if antenna is to be replaced)
-Possibility of firmware upgrades (for bug fixes)

Radio Transmitters:

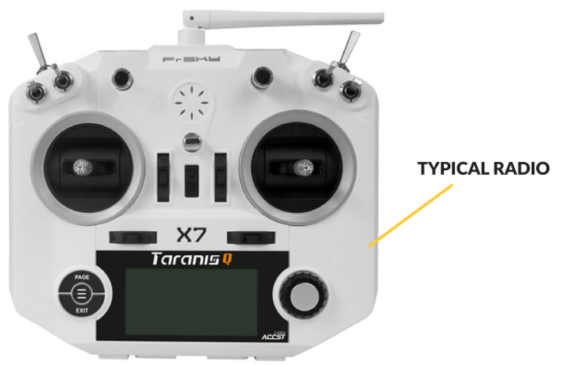
An FPV Drone Radio Transmitter is an electronic device that uses radio signals to transmit commands wirelessly via a set radio frequency over to the Radio Receiver, which is connected to an aircraft or multirotor being remotely controlled. In other words, it's the device that translates pilot's commands into movement of the multirotor.

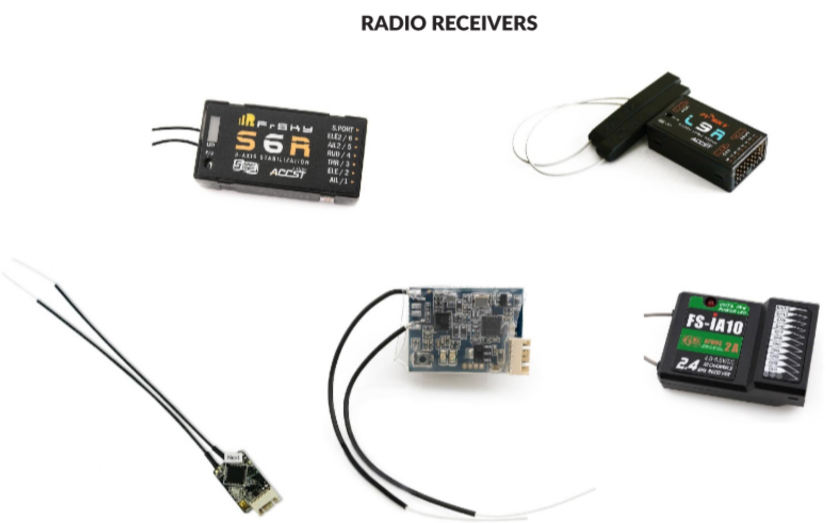
Frequencies:

Transmitter commonly use the following frequencies: 27MHz, 72MHz, 433MHz, 900MHz, 1.3GHz and 2.4Ghz

433Mhz, 900Mhz and 1.3GHz are typically used in long range Mission Drones and RC systems.

2.4GHz is most popular frequency. It is a newer technology and it offers "frequency hopping" which does the job of managing multiple users frequency transmitting at the same time. This id done by scanning the frequency band and finding the best available channel during the transmission. 2.4GHz antennas are very compact as well. Generally speaking the lower the frequency, the larger the antenna. For that reason, 2.4GHz quickly became the "go to" frequency.





Telemetry:

Drone telemetry is data gathered about the aircraft and its surroundings that is sent back to the operator or ground control station (GCS). This information may be taken from the drone's autopilot, sensors such as accelerometers, gyroscopes and GPS, or from subsystems such as the aircraft's power source.

Tracking Telemetry:

Telemetry data provides the ability to track UAV status in real time, allowing pilots to monitor position, attitude and altitude to ensure smooth and efficient flight. Depending on the sensors installed on board, it may also provide information on components and subsystems such as the RPM of the rotors and the voltage level of the batteries.

Drone telemetry data is transmitted via radio, often on a separate link to the drone control signals to provide increased safety. This requires the drone to have an onboard radio transmitter as well as a receiver, and appropriate antennas. Common drone radio telemetry frequencies include 433 MHz, 915 Mhz and the newer 2.4 GHz. Wireless telemetry data can also be transmitted via Wi-Fi, which typically has a shorter range than other radio technologies but provides higher data rates.

FPV Telemetry:

Another form of telemetry is FPV (first-person view), in which a video feed from an onboard camera is transmitted back to the drone pilot and displayed on a monitor or a pair of FPV goggles. This allows the pilot to see exactly what the drone "sees", and in good communication environments, can provide a unique form of real-time situational awareness.

Telemetry Modules

Ground Station

GPS/GNSS:

GNSS (Global Navigation Satellite System) is a standard term for any satellite-based navigation system that provides geo-spatial positioning data with global coverage. The most well-known GNSS is the United States-developed GPS (Global Positioning System). Other GNSS signals include Russia's GLONASS, the European Union's Galileo, and China's Beidou.

UAV GPS/GNSS Receivers:

Many unmanned systems such as UAVs, UGVs and AUVs require the use of GPS/GNSS to provide them with a high degree of positioning accuracy. A GNSS antenna is mounted somewhere on the vehicle that receives location and time data from GNSS satellites. This data is then usually fed into the avionics, autopilot or navigation systems of the vehicle, and can also be used to determine velocity.

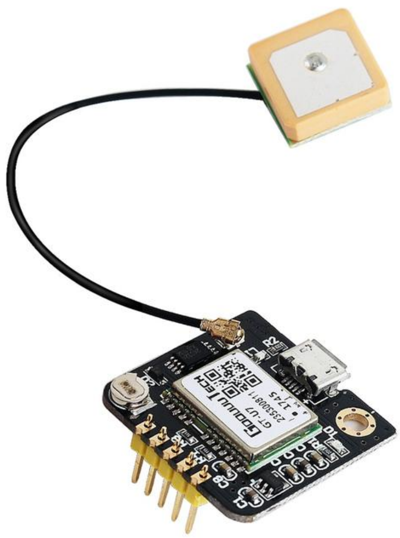
In addition to navigation, unmanned vehicles may use GNSS to georeference gathered data, avoid collisions, or provide a tracking facility. The GNSS data provides inputs to the control loop of a drone or other autonomous vehicle, allowing it to maintain position, return to home or follow a series of preset waypoints. This is particularly important for waterborne robots such as AUVs and ROVs whose positions can be significantly affected by tidal activity.

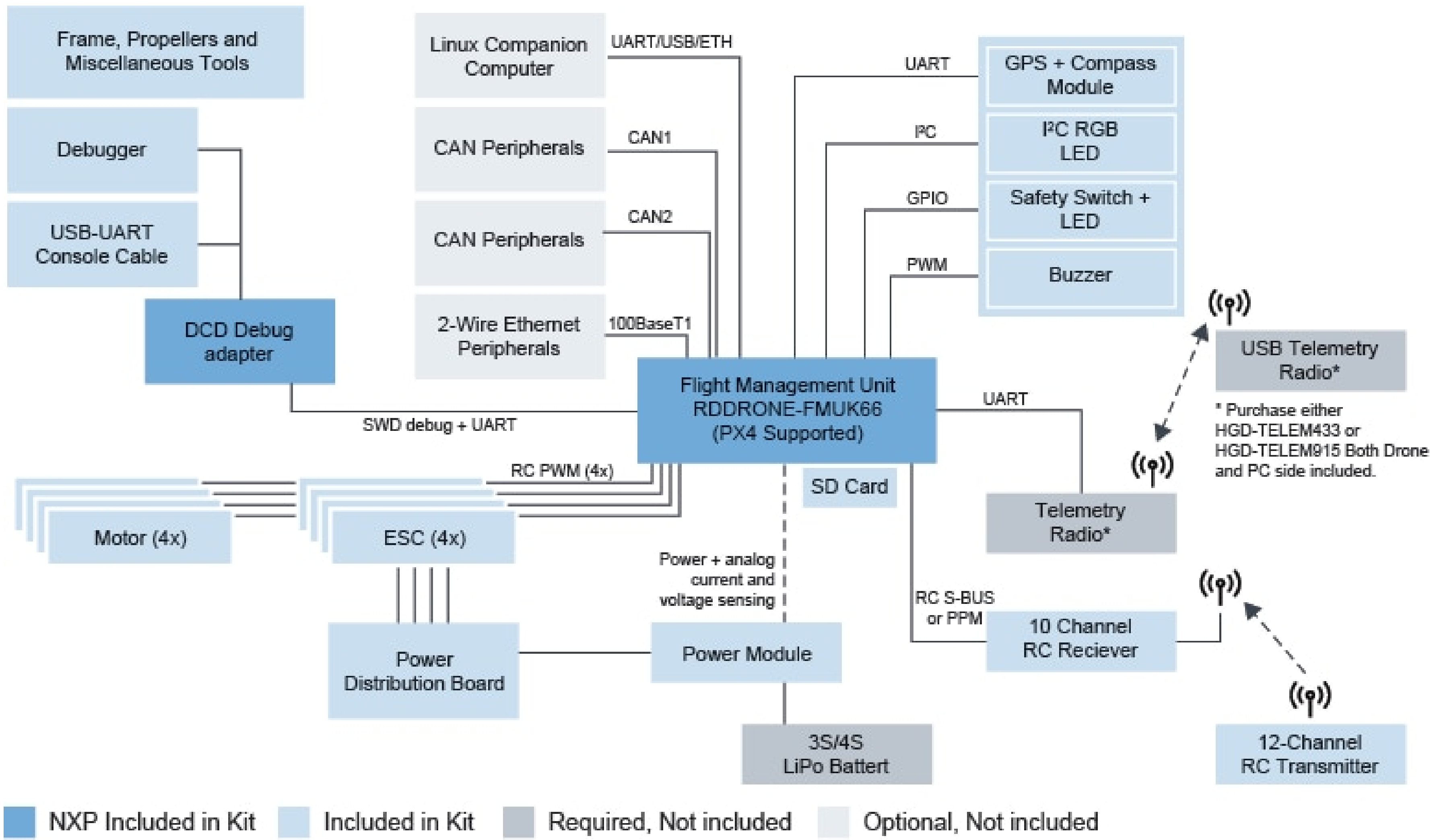
GNSS faces the limitation of needing to be within line of sight of at least four satellites in order to provide reliable navigation. In poor signal environments it can be advantageous to couple the GNSS with an Inertial Navigation System (INS), which uses rotation and acceleration information to calculate a relative position that can be used for navigation during loss of GNSS signal. In turn the GNSS can provide an external reference to the INS that helps reduce the effect of bias errors.

Drone GPS/GNSS:

Consumer-grade drones are typically built with a GNSS receiver that provides accuracy to around 2-3 metres. In order for such a system to be useful for high-accuracy data gathering such as aerial imagery, the data needs to be referenced to the same coordinate system as the GIS database. This can be achieved by using ground control points (GCPs) or Direct Georeferencing. By determining more precise GNSS coordinates, drone mapping software can then accurately position its output in relation to the real world.

In addition to GPS/GNSS antennas, GNSS-INS / GPS-INS and GPS/GNSS receivers, GNSS simulators and GNSS signal generators are also important components for accurate and precise positioning solutions.





EXAMPLE SYSTEMATIC PLAN OF THE MISSION DRONE (PIXHAWK4 BASED)

Number	UAV - 0001	Page	12 of 13
Date of Writing	6.12.2021	Revision	4
Applicability	None	DRAWN BY: WEB SEARCH	DATE: ?
Prepared	Software Team Member	CHECKED BY: E. PEHLEVAN	DATE: 6.12.2021

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