UAS PERFORMANCES II

DRONE PILOT COURSE

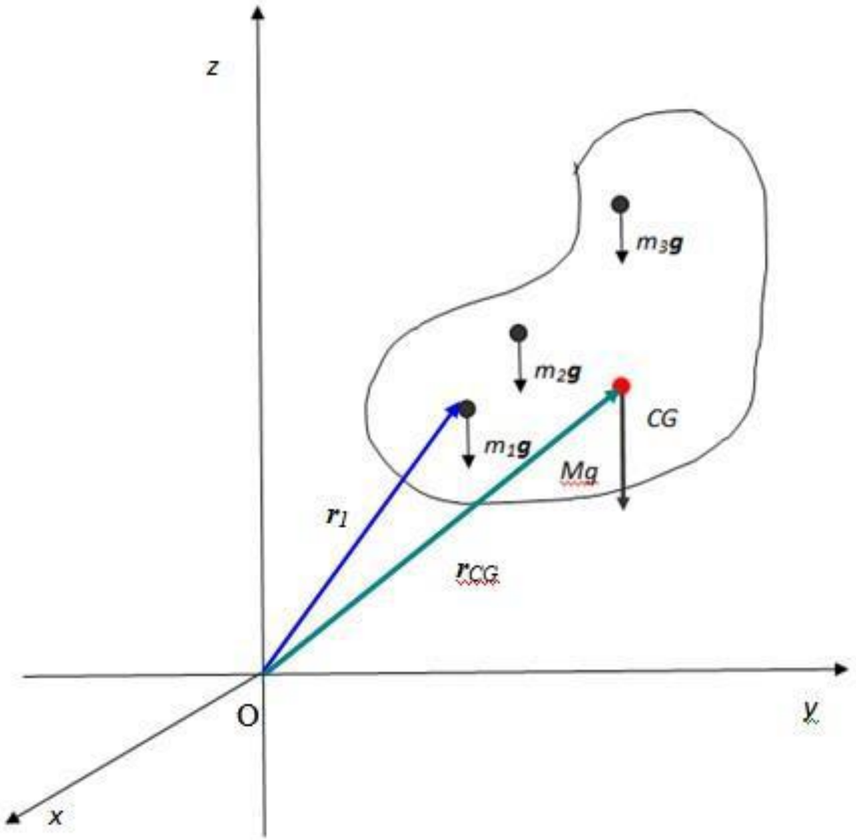
CENTER OF GRAVITY (CG) & MASS BALANCE

<u>CENTER OF GRAVITY (CG) AND MASS BALANCE</u>

Different types of forces act on a UAS:
- Aerodynamics (Lift and resistance)
- Propulsive (Thrust)
- Gravitational (Weight)

The forces are defined as a pressure applied to a surface, but for the purposes of simplifying the calculations, punctual forces are taken (applied at a single point) whose effect on the body is equivalent to the application of pressure on the entire surface.

The point at which point forces must be applied to achieve this equivalence is called the center of gravity (CG).



CENTER OF GRAVITY (CG) & MASS BALANCE

PAYLOAD STABILITY

When the sum of all the forces acting on a body is zero, the body is said to be in equilibrium and, therefore, will not move.

The payload are those elements that can be incorporated into a UA, but are not essential for its operational envelope and to be able to take flight. The payload shifts the center of gravity.

The objective is that the center of gravity always remains centered, so that the UA is stable. To do this, the weight of the payload or the installed gimbal must be as aligned as possible with the CG of the UA.

CENTER OF GRAVITY (CG) & MASS BALANCE

<u>PAYLOAD STABILITY</u>

Depending on where the payload is placed, the UA's center of gravity will vary. Must take into account.

- If the CG is low, the UA will make slower and smoother movements.
- If the CG is high, the UA will make faster and more jerky movements.
- If the CG does not coincide with the geometric center, the UA will be unstable.

CENTER OF GRAVITY (CG) & MASS BALANCE

PAYLOAD STABILITY

There can be several factors that affect the decision of where to place the payload.
Looking only in terms of stability and taking into account that the weight of the payload (for example, a camera) is applicable:

UNSTABLE

The payload is off center/offset too much on the longitudinal axis (forward or aft) or lateral axis (offset left or right) and/or above the plane of the propellers on the vertical axis. This configuration shifts the center of gravity away from the geometric center.

STABLE

The payload is centered on the longitudinal and lateral axes of the UA, and is also located below the original CG of the UAS. It is the ideal and most stable configuration.

CENTER OF GRAVITY (CG) & MASS BALANCE

STABILITY IN OTHER UA TYPES

In a fixed-wing UA, longitudinal static stability is given by the positional relationship between the CG and the aerodynamic center, which is the equivalent point at which all forces of a purely aerodynamic nature would be exerted if these forces were punctual.

To study the longitudinal static stability, a headwind gust that generates a disturbance in the aircraft is considered.

According to the relative position between the aerodynamic center (CA) and the center of gravity (CG), three cases are distinguished:

CENTER OF GRAVITY (CG) & MASS BALANCE

STABILITY IN OTHER UA TYPES

1. **CG Position=CA Position**

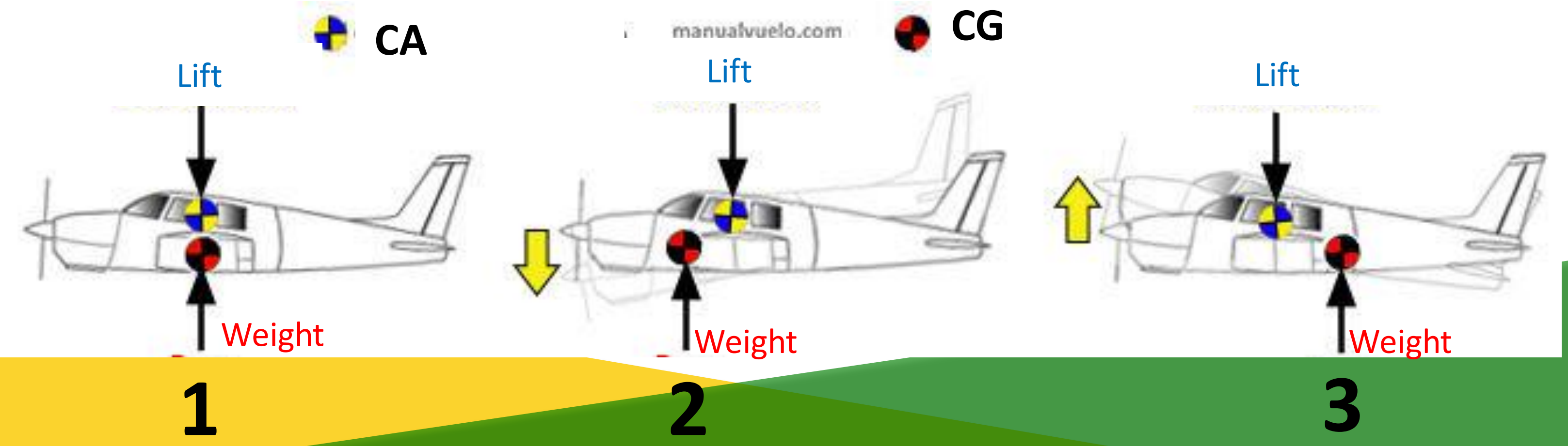
   The disturbance will increase the aircraft's lift. Since the CA is in the same place as the CG, the total force will be vertical, causing the UAS to rise in height. It is considered neutral stability.

2. **CG position more forward than CA**

   The disturbance will increase the aircraft's lift, causing it to lift its nose. As the CG is further forward, the weight of the aircraft will lower the nose again, returning it to the starting position. It is considered stable.

3. **CG position further back than CA**

   The disturbance will increase the aircraft's lift, causing it to lift its nose. With the CG further aft, the weight of the aircraft will help keep the nose up until the aircraft stalls. It is considered unstable.



CENTER OF GRAVITY (CG) & MASS BALANCE

STABILITY IN OTHER UA TYPES

Based solely on stability criteria, it can be concluded that, for a fixed-wing UA to be statically stable, the ideal is for the CG to be slightly ahead of the CA.

If the CG is too far ahead of the CA (for example, in the nose of the plane) it will not be good either, since it will be difficult for you to take off.

Taking into account that the CA is located on the wing, the CG should be at the leading edge, approximately. That is, at the beginning of the wing.

The payload being added to a fixed-wing UA should be positioned so that its CG matches the CG of the UA.

PAYLOAD ASSURANCE

PAYLOAD ASSURANCE

The payload is the part of the UA that gives meaning to the aircraft, since it is the reason for carrying out an operation.

Payloads can be cameras, merchandise, speakers, sensors...

Payloads can be:
- Fixed
- Interchangeable

In both cases, it is essential to check before each flight that they are perfectly secured to the aircraft. A poorly secured payload can not only detach from the aircraft with the risk that this entails, but it can also affect the center of gravity of the UAS, generating flight instability.

PAYLOAD ASSURANCE

PAYLOAD ASSURANCE

To ensure the payload it is important to take into account the previous concepts about center of gravity and mass balance.

If the payload is variable (for example, a tank), it is essential to secure it in such a way that its effect on the aircraft's center of gravity is minimal.

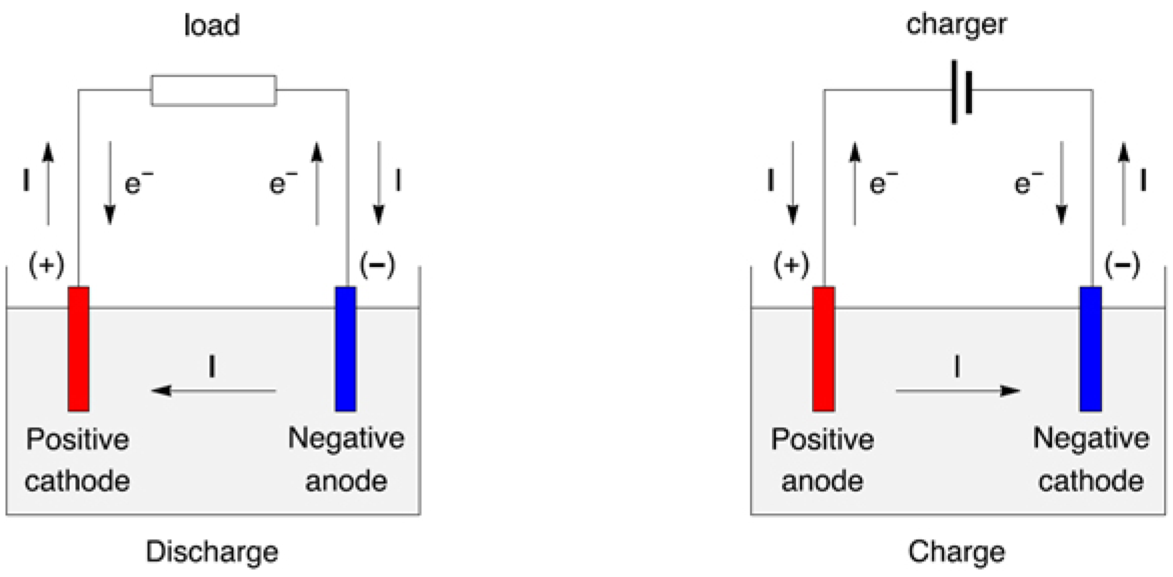
Payload securing systems range from bolted joints, open/close systems, to more complex systems, such as silentblocks that reduce vibrations or integrated mechanisms specific to each UAS.

BATTERIES

POWER SUPPLY OPERATION

A battery is an electrochemical device that converts stored chemical energy into direct current electrical energy.

- In the middle of the cell, positively charged ions migrate to an electrode called the cathode through an electrolyte. In the other half of the cell, negatively charged ions migrate to the electrode called the anode through an electrolyte, as shown in Figure. An electrical charge can be placed between the battery cables.
- Batteries operate with a closed thermodynamic cycle.



BATTERIES

BATTERY TYPES

Batteries can be rechargeable or single use. Non-rechargeable batteries are known as primary, and rechargeable batteries are called secondary.

Primary cells may have superior performance characteristics and may be the best option for single use electric aircraft. The cost of replacing batteries is generally prohibitive for multi-use UAS, and so secondary batteries are used for these applications.

PRIMARY BATTERY

- Not rechargeable
- Unique life cycle
- Single battery circuit
- They produce little electricity
- It is durable
- Common: Leclanché or dry cell and mercury battery

SECONDARY BATTERY

- Rechargeable
- Multiple life cycle
- Contains 3 to 6 battery circuits
- The most common, lead acid (for cars)
- Extremely high electrical current
- Sells out quickly

BATTERIES

BATTERY TYPES

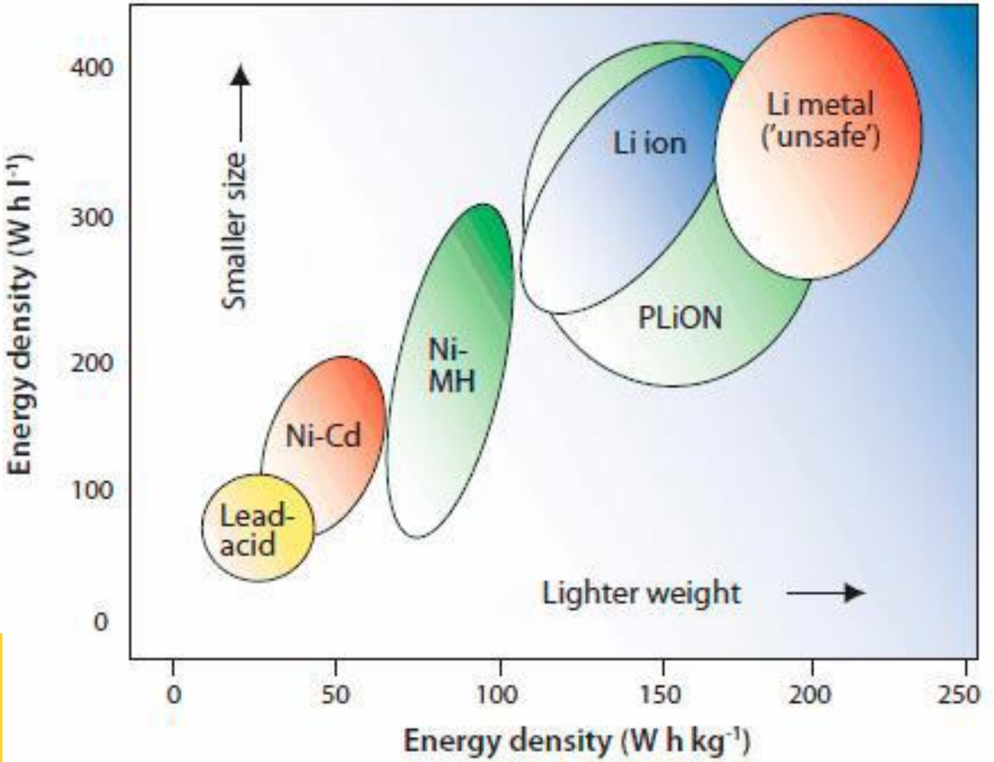
Main types and characteristics of secondary (rechargeable) batteries

Battery type	Theoretical specific energy (Wh/kg)	Practical specific energy (Wh/kg)	Specific power (W/kg)	Voltage (V)
Lead acid (Pb/acid)	170	30-50	180	1,2
Nickel-Cadmium (NiCd)	240	60	150	1,2
Nickel-Metal hydride (NiMH)	470	23-85	200-400	0,94-1,2
Lithium-Ion (Li-Ion)	700	100-135	250-340	3,6
Lithium-Polymer (Li-Po)	735	50,7-220	200-1900	3,7
Lithium-Sulfur (LiS)	2550	350	600-700	2,5

BATTERIES

BATTERY TYPES

- Energy density is the amount of energy that a battery offers in relation to its density (weight and size).
- Of the currently existing batteries, the ones that offer the highest energy density are the lithium metal ones, but they are very unstable and dangerous.
- The next group is made up of Li-Ion and Li-Po batteries (the most used in UAS).



BATTERIES

<u>LiPo BATTERIES</u>

LiPo (Lithium Polymer) batteries are a type of rechargeable battery that are often used in radio control electrical systems, especially in aircraft.

When compared to Nickel Cadmium NiCd and Nickel Metal Hydride NiMH batteries, LiPo batteries have 3 important advantages that make these batteries the perfect choice for RC flights:

1. LiPo batteries are more stable during the charging process.

2. LiPo batteries have high energy density which means they store more energy in a smaller size.

3. LiPo batteries have a high discharge rate to power the most demanding electrical systems.

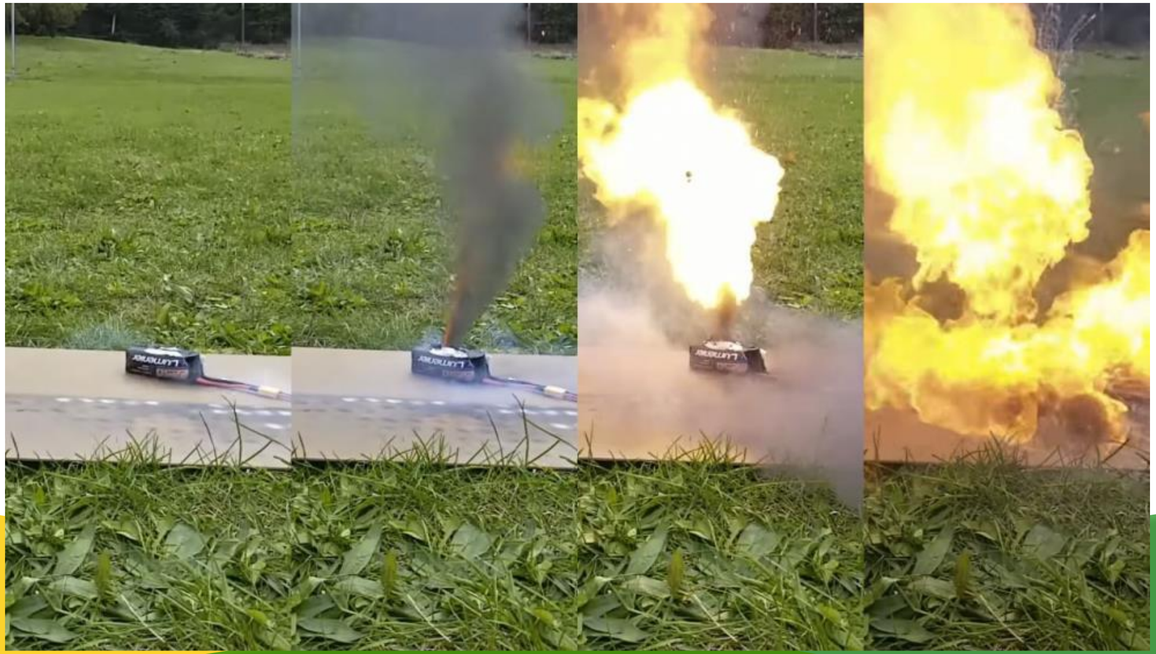
BATTERIES

<u>LiPo BATTERIES</u>

However, they present safety problems due to the volatile electrolyte, which can deflagrate.

Furthermore, RC LiPo batteries require unique and proper care to make them last much longer than any other technology. Charging, discharging and storage all affect the life expectancy of the battery.

Unlike NiCd or NiMH batteries which contain 1-2 volt cells, LiPo batteries have nominal 3-7 volt cells, 4-2 volts when fully charged.

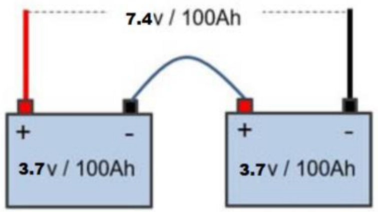


BATTERIES

VOLTAGE

The usual nomenclature to indicate the voltage presented by the battery is given by the number of cells connected in series, referring to its nominal voltage of 3.7 V. That is, if the battery has 7.4 V, it means that there have been connected two 3.7V cells in series, so the battery will be indicated as 2S. More examples are included below.

- 3,7V Battery = 1 cell x 3,7 Voltage (1S)
- 11,1V Battery = 3 cells x 3,7 Voltage (3S)
- 22,2V Battery = 6 cells x 3,7 Voltage (6S)



2S Battery

Two batteries connected in series is equivalent to a battery whose voltage is the sum of the voltages of the two batteries and whose capacity is the same. It is important that the capacity of the two batteries connected in series is equal.

The series connection is made by connecting the negative pole of one battery with the positive of the next, leaving the positive and negative ends of the set as the poles of the equivalent battery.

BATTERIES

CAPACITY

The capacity indicates how much energy the battery can hold and is indicated in milliamp hours mAh This is a way of indicating the amount of electricity measured in milliamps that the battery can deliver for 1 hour to fully discharge itself.

For example, a LiPo battery with a capacity of 2000 mAh will be able to offer 2000 mA and it will take 1 hour to discharge them constantly. However, if the UA only needed 1000 mA constant, it would take 2 hours to deplete the battery.

The main thing is that if you want more runtime you need to increase the battery capacity. Unlike voltage, the capacity can change to give more or less usage time.

Of course with size and weight restrictions, battery capacity is limited. The larger the battery capacity, the larger its weight and size.

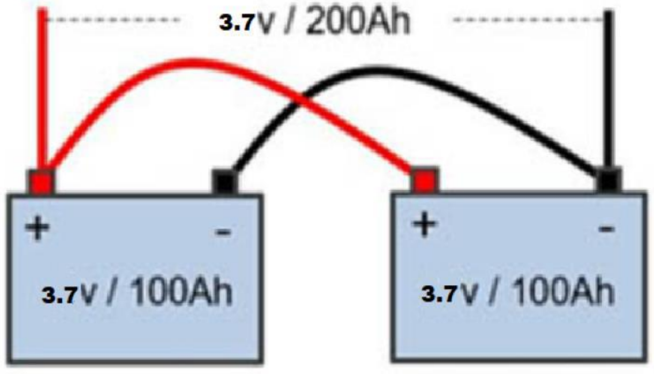
BATTERIES

CAPACITY

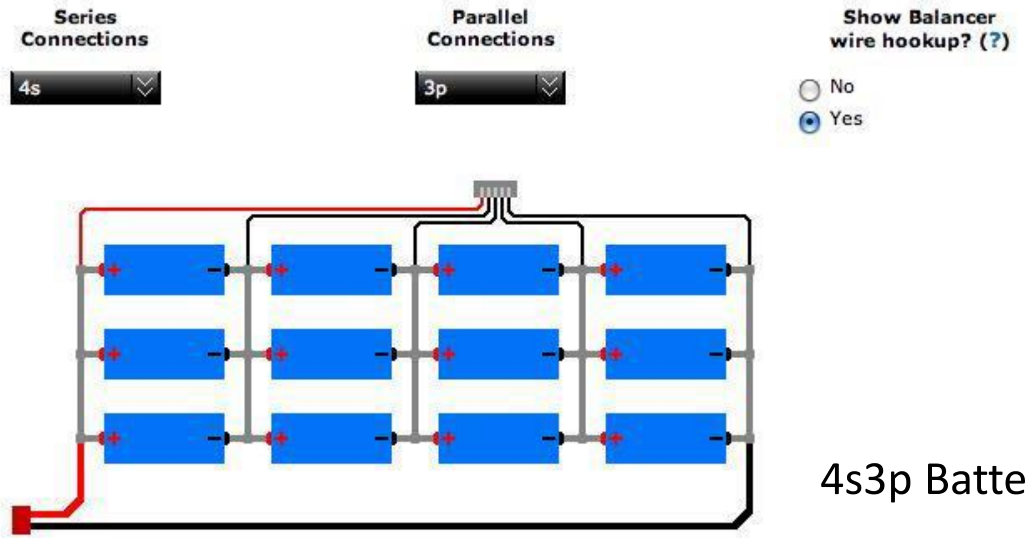
Two batteries connected in parallel is equivalent to a battery whose voltage is the same and the capacity is the sum of the capacities of the two batteries.

Parallel connection is indicated with the letter " and is made by connecting the negative poles to each other and the positive poles to each other, resulting in a single positive pole and a negative pole.

Serial and parallel connections can also be combined.



2p Battery



4s3p Battery

BATTERIES

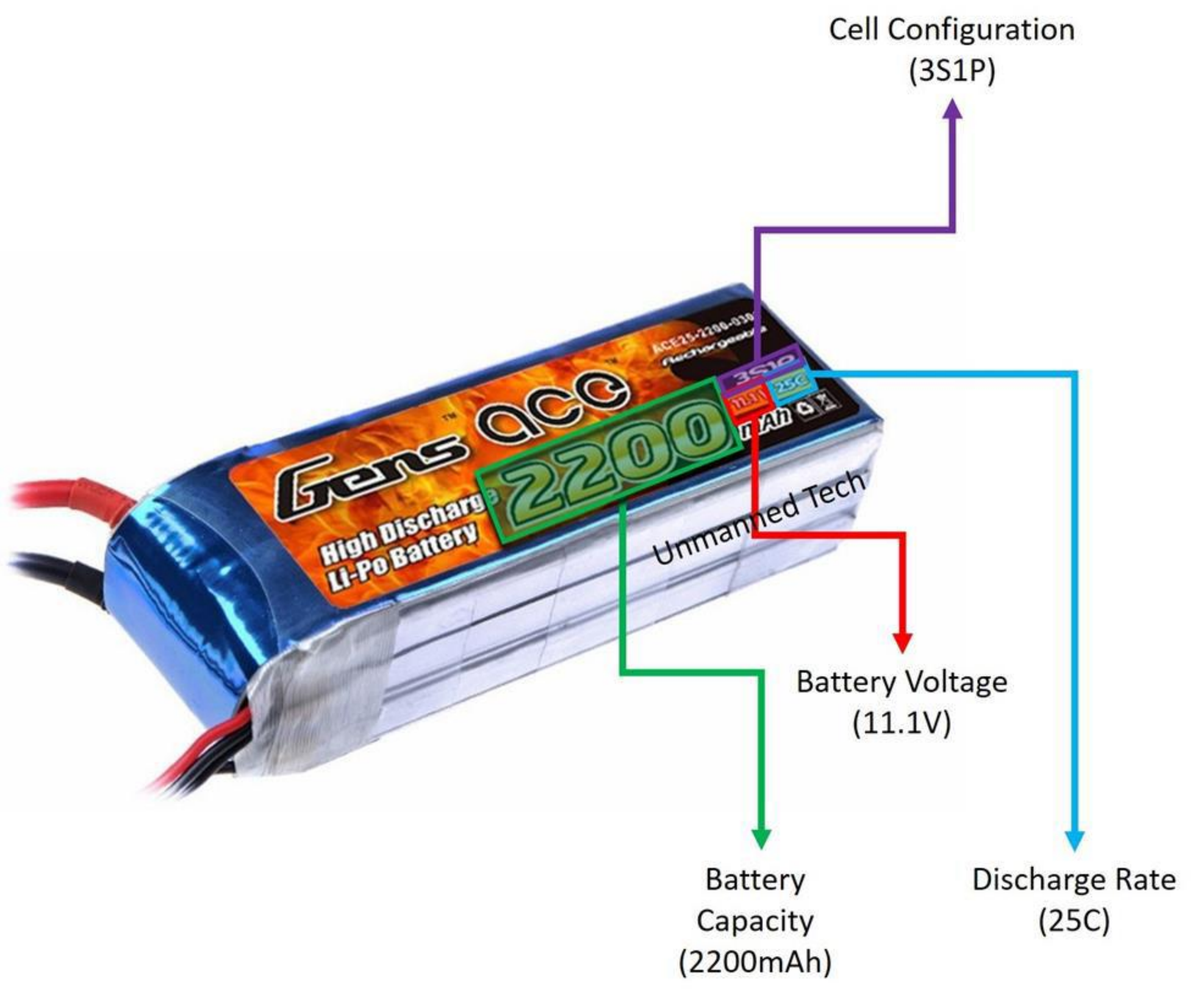
C-RATE

Another important property of LiPo batteries is the rate of discharge. The rate of discharge is simply how much electrical current it is capable of continuously providing without being damaged.

This discharge rate is called "C". A battery with a discharge rate of 10C discharges at a rate of 10 more than the battery capacity, 15C = 15 times, 20C = 20 times, and so on.

A 1000mAh 15C battery will be able to deliver 15A continuously without being damaged (1000mA x 15C = 15A).

A 2500mAh 30C battery will be able to deliver 75A continuously without being damaged (2500mA x 30C = 75A).



BATTERIES

CHARGE AND DISCHARGE

- Selecting the correct charging current is critical when charging a LiPo battery.

- The generally used rule of thumb is to never charge a LiPo to more than 1x its capacity (1C).For example a 2000 mAh battery should be charged at a maximum current of 2000 mA (2A).

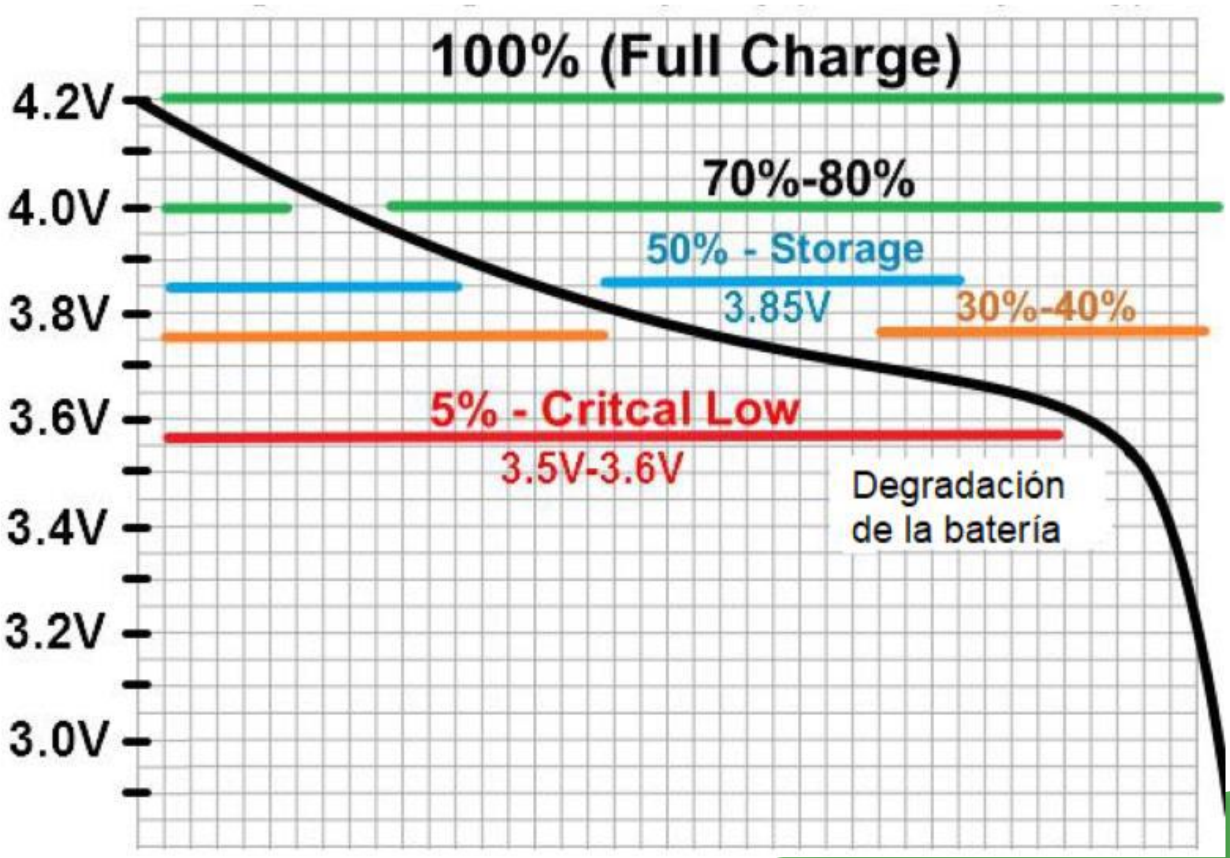
- Batteries with more than 1 cell (2s or more) must be charged taking into account the voltage of each cell. This is called balancing and is a function of LiPo chargers. It is not convenient for some cells to be more charged than others, since it would unbalance the voltage between cells and, therefore, the series connection between cells would no longer be with elements of the same voltage, a requirement for this type of connection. If this occurs with a difference of ±0.2 V, the battery becomes dangerous and precautions should be taken with it.

- The three main things that shorten battery life are
    - Heat
    - Over discharge
    - Improperly balanced

BATTERIES

CHARGE AND DISCHARGE

- At the other extreme is overdischarge.
- LiPo cells should not drop below 3 3 V, being from 3 0 V when they begin to degrade and lose their qualities.
- If a battery is too discharged, it should be charged to 3 8 V/cell for storage. This is the balance or storage point.
- Smart batteries have internal resistors that automatically lower (but not raise) the battery voltage to the balance point by giving off heat.
- If the battery is not smart, it is advisable to use a balancing charger to store the batteries at 3.8V/cell.



BATTERIES

BATTERY OPERATION

The batteries discharge electrical current at the demand of the system that consumes said energy. So:

- It is necessary to evaluate how much the system consumes.
- A battery capable of supplying such energy must be chosen.
- You have to assess how long the battery will last supplying electricity to the system.

BATTERIES

BATTERY OPERATION

Battery operation example:

- A 2 kg UAS is available in hexacopter configuration and it is obtained from the specifications that each motor lifts 0.5 kg consuming 10A. If each motor lifts 0.5 kg, the 6 motors of the hexacopter will lift 3 kg. The UAS weighs 2 kg, so we can use a maximum 1 kg battery.

Conclusions:

1. The consumption of the 6 motors to lift those 3 kg will be 60 A.
2. If we use a 3000 mAh 10 C 4s1p battery, the continuous discharge will be 30 A (3000 mA per 10 C), so it will not be able to reach the 60 A required by the UAS.
3. We need to look for a battery with more discharge (higher "C") or more capacity. We already know that capacity increases weight, and we only have 1 kg.
4. We will try a 4s1p of 3000 mAh and this time 30 C. Now the continuous discharge will be 90 A, it already covers the 60 A required.
5. This battery is capable of offering 3 A for 1 hour, but we need 60 A, so doing the calculation, this battery will last 3 min. It is quite little, so it would be convenient to increase the capacity (this allows lowering the C-rate).
6. The definitive one will be a 4 s 1 p battery of 7000 mAh and 10 C. Continuous discharge of 70 A and autonomy of 7 min. It would only be necessary to make sure that it weighs less than 1 kg so that everything fits.
7. Note The voltage is not varied (it is always 4s) as it is a requirement of the UAS that it works at that voltage.

BATTERIES

BCN DRONE CENTER

RECOMMENDATIONS FOR USE

1. Do not discharge batteries more than 3.3V per cell.
2. Do not charge batteries to more than1 C.
3. Always use swing mode if the batteries are not smart.
4. Always store batteries at their balance point (3.8 V/cell).
5. Do not expose batteries to high temperatures.
6. Arrange the batteries in the UAS with a cooling system.
7. Store batteries in fireproof bags.
8. Let the battery rest for at least 15 min between charging and use.
9. Do not leave the loading zone unattended during the charging process.
10. Install a smoke detector in the cargo area.
11. Carry a fire extinguisher whenever LiPo batteries are used.
12. Do not use swollen batteries.
13. Dispose of dangerous batteries.

BATTERIES

<u>DISPOSAL OF BATTERIES</u>

When a battery is swollen, has unbalanced cells, has discharged any cell below 3.3V, or suspects it may be a dangerous battery, it should be disposed of immediately.

To dispose of a battery you must put it in a container with water and salt.

This will completely discharge the battery and stop being dangerous.

Later, you must take it to the battery recycling point available at your nearest clean point.

Thanks for your attention

DRONE PILOT COURSE