Accordo tra il CSLLPP ed il Consorzio ReLUIS
attuativo dei DM 578/2020 e DM 204/2022

Attività di formazione per i tecnici degli Enti Locali

Modulo III - Modelli informativi digitali e tecnologie innovative

coordinatori Proff. Edoardo Cosenza e Mauro Dolce

Napoli

Lezione 3
Droni aerei per operazioni in ambito civile

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Outline

- Introduction
- Drone taxonomy
- Drone components
- How it works
- Photogrammetry
- *Overview of the current European Aviation regulation for Aerial Robots*

Introduction

What is a Drone?

- **D**ynamically **R**emotely **O**perated **N**avigational **E**quipment
- A powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload.
- Other names?
  - Unmanned Aerial Vehicle
  - Remotely Piloted Aerial Vehicle
  - Remotely Piloted Aircraft System

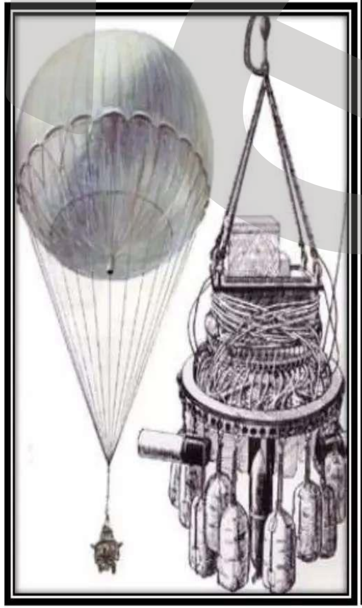
Acronyms

- UAV – Unmanned Aerial Vehicle
- UAS – Unmanned Aerial System
- RPV – Remotely Piloted System
- ROA – Remotely Operated Aircraft
- UVS – Unmanned Vehicle System

History

- Leonard Da Vinci's notes
- First autonomous flight of an unmanned aerial vehicle (UAV) on 1896
  - Number 5 vehicle, designed by Samuel P. Langley, that travelled 400 meters
  - Number 6 vehicle travelled 1600 meters
- In 1916, during the First World War, the Aerial Target vehicle was radio controlled (RC)
- Hewitt-Sperry vehicle in 1916

History




Today in 1849: Austria drops a bomb on Venice from an unmanned balloon. History's 1st air raid ...and drone strike.

History

1960: DoD Initiated the "Red Wagon" program for UAV after Russia downed U-2

History – First Proof of the UAV Concept

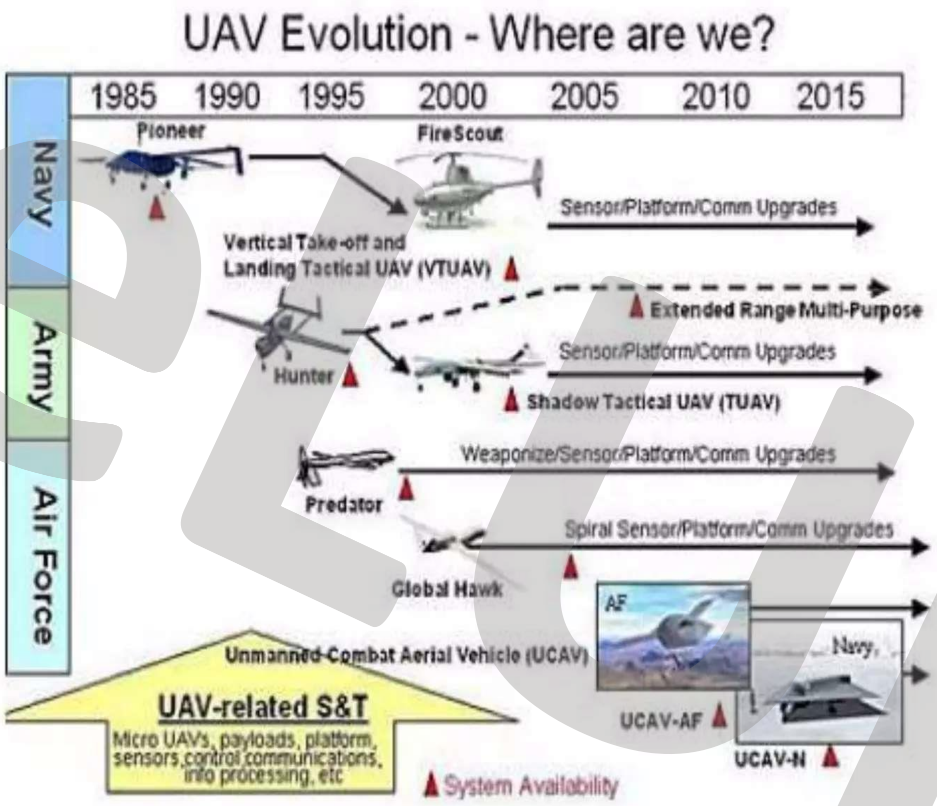
1973 Syrian Surface-to-Air Missile

1982 Israel UAV

History

- Before the Second World War the airplanes were converted into autonomous vehicles controlled by autopilots
  - The first society, the *Radioplane Company*, specialized in building was founded by Reginald Denny
  - 1500 radio-controlled helicopters were built for the Second World War
- Technological development, smaller processors, lightweight sensor measurement systems, global navigations systems and so on boosted UAVs growth
  - In Japan, Yamaha Motor company developed an unmanned helicopter for irrigation in 1983
  - An autonomous UAV flying with GPS was out in 1988
    - It observed volcanic activities at Usu-zan in 2000

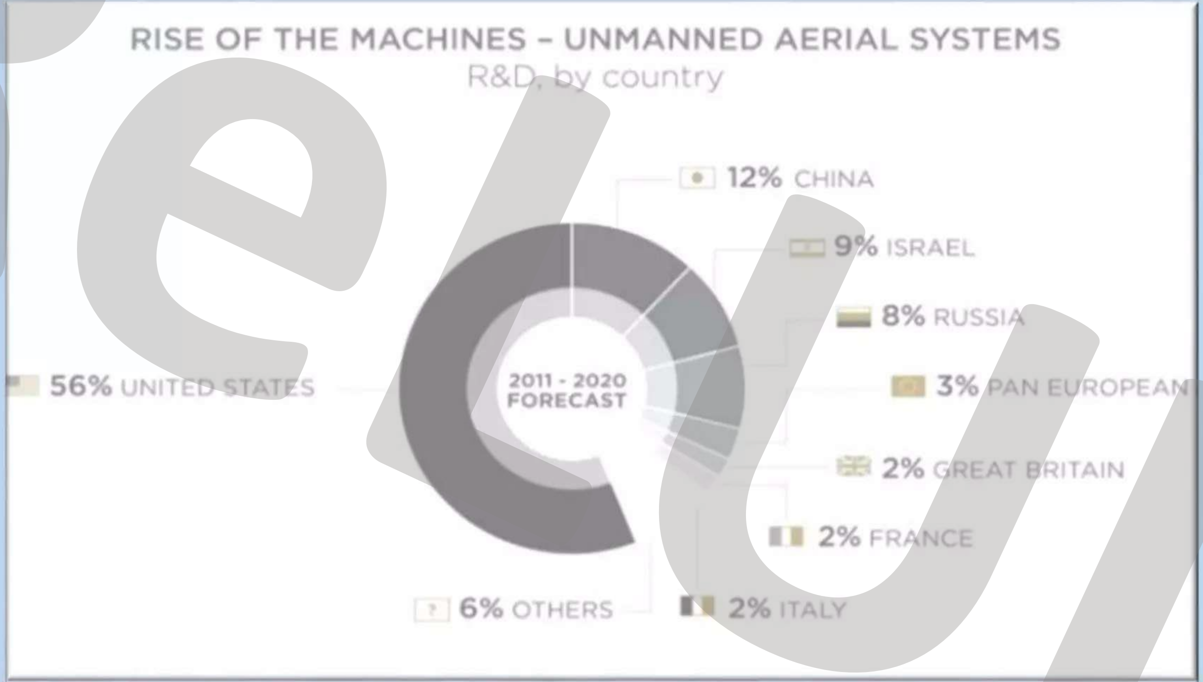
Evolution of Drones




amazon.com
NEWS
Shipping
Domino's
Shipping
NETFLIX
Shipping
Construction Site Monitoring
Wild Life Monitoring
Application of Drones
Farm Animal Monitoring
Farming
Fertilizing
Fertilizing


Power Line Monitoring
Cell Tower Monitoring
Boundary Monitoring
Application of Drones
City Event Monitoring
Traffic Monitoring
City Monitoring
Emergency Responding
Emergency Responding
Recreational Purposes

Countries Designing and Building Drones



Drone Technology - Key Facts

- $82 Billion Industry in the US
- Civil drones will be 10% of the aviation market by 2025
- 195 UAV manufacturers worldwide
- Over 100,000 jobs by 2020
- Smallest UAV is 2.8lbs
- Largest UAV is 76,000lbs
- Drone can be 5 centimeters to 50 meters

Drone taxonomy

Fixed-wing UAVs

- They require a track to take off and land
- High robustness, high cruise velocity

Rotary-wing UAVs

- Vertical take off and landing (VToL) vehicles
- Hovering
- High manoeuvrability
- Helicopters, quadrotor, hexarotors, ….

Tilted / Tilting

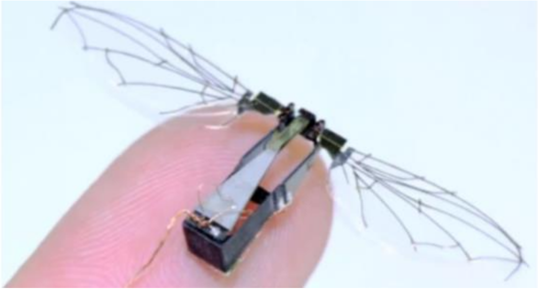
- Tilted (passive)
- Tilting (active) configurations

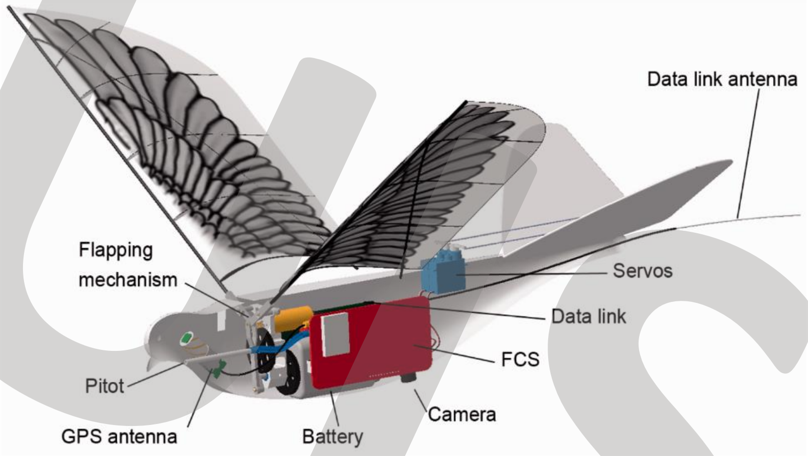
Blimp

- Lighter-than-air
- High robustness
- Low velocity

Flapping wing

- Bio inspired





Taxonomy about dimension and flight time

- HALE (High Altitude Long Endurance)
- MALE (Medium Altitude Long Endurance)
- Tactical UAVs
- Small and man-portable UAVs



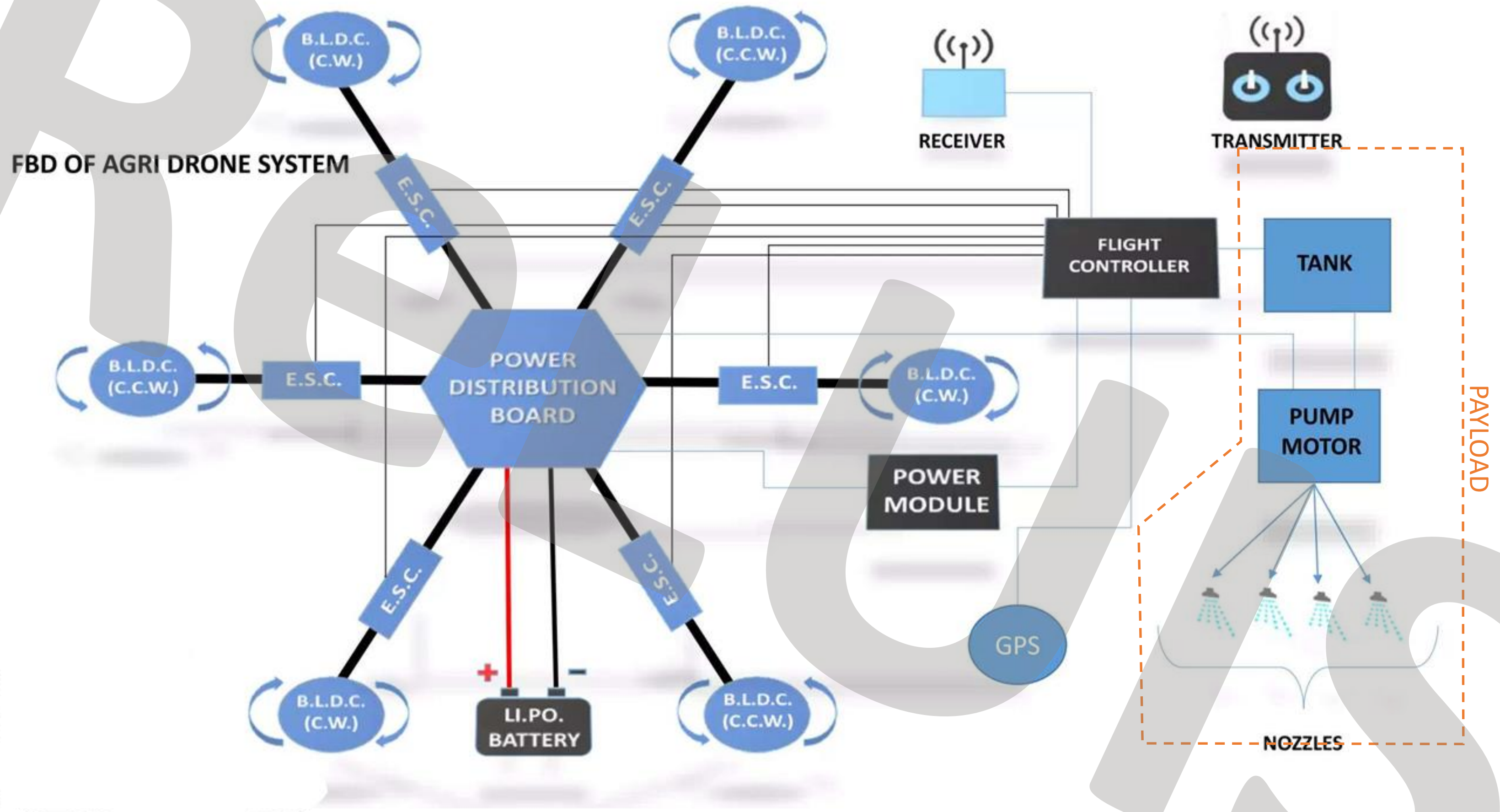
Taxonomy about propellers number and configuration

- Configuration
  - Plane
    - All propellers on the same plane
  - Coaxial
    - Pairs of propellers aligned along each axis
  - Omnidirectional (passive tilted)
    - Propellers not aligned in the same direction
  - Cross (+) or X configuration
- Number of propellers (usually multiple of 2)
  - Quad-copter: 4 propellers
  - Hex-copter: 6 propellers
    - Plane or Y6 (coaxial-tri-copter)
  - Octa-copter: 8 propeller
    - Plane or X8 (coaxial quad-copter)

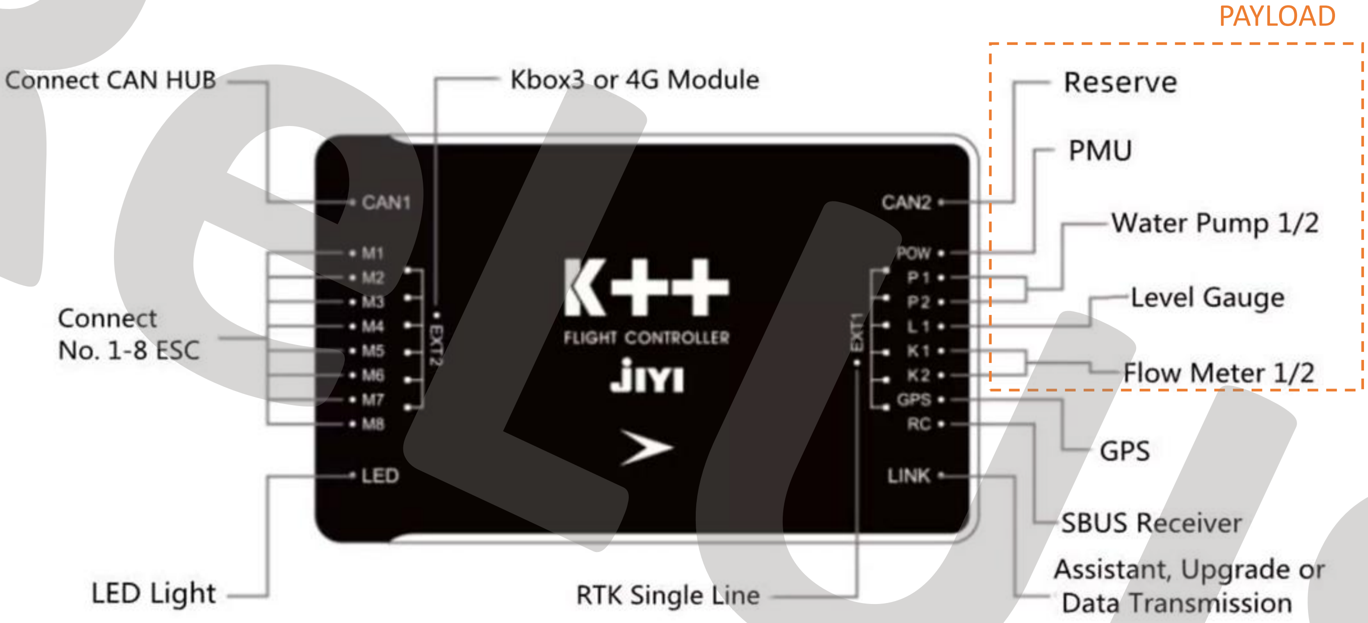
Drone components

COMPONENTS OF MULTI COPTER DRONE

- FLIGHT CONTROLLER
- BATTERY
- BLDC MOTOR
- ELECTRONIC SPEED CONTROLLER
- POWER MODULE
- PROPELLERS
- POWER DISTRIBUTION BOARD
- GPS
- LANDING GEAR
- TRANSMITTER AND RECEIVER
- TELEMETRY


FBD OF AGRI DRONE SYSTEM
B.L.D.C. (C.W.)
B.L.D.C. (C.C.W.)
RECEIVER
TRANSMITTER
E.S.C.
FLIGHT CONTROLLER
TANK
POWER DISTRIBUTION BOARD
PUMP MOTOR
PAYLOAD
POWER MODULE
GPS
LI.PO. BATTERY
NOZZLES

Flight controller:



Flight controller:

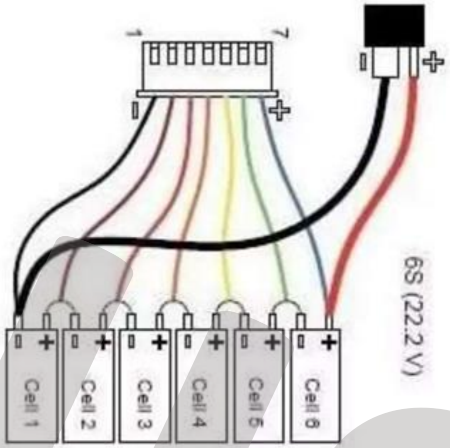
- A flight controller (FC) is **a small circuit board of varying complexity**. Its function is to direct the RPM of each motor in response to input.
- A command from the pilot for the multi-rotor to move forward is fed into the flight controller, which determines how to manipulate the motors accordingly.
- The Flight controller is the **brain of the drone**.
- It's a circuit board with a range **of sensors that detect movement of the drone, as well as user commands**.
- Using this data, it then controls the speed of the motors to make the drone move as instructed.

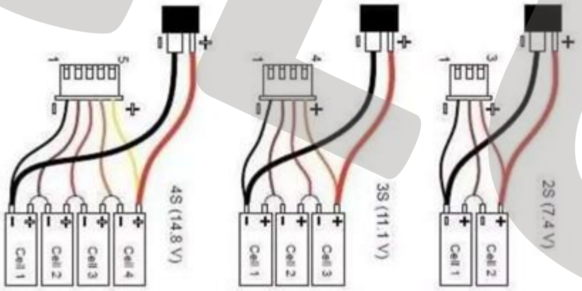
Type of Flight Controller

- K++, K++pro
- K++V2
- K3, K3Apro
- DJI N3 AG
- Topxgun TIA

Battery:

- Commonly nickel based and lithium based batteries are known
- Lithium based batteries are mostly used due to best performance.
- Lithium batteries has two most commonly used batteries are:
  1.Lithium ion battery (eg. Mobile batteries etc)
  2.Lithium polymer battery (eg. Quadcopter , helicopter etc.)

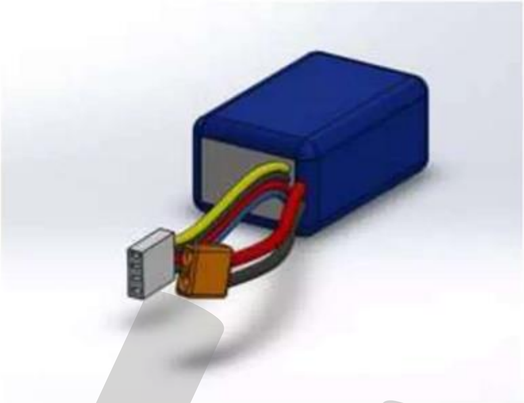




Battery:

Purpose of using Li-Po Battery:

- Li-po batteries are used in drones due to best performance as compared to li-ion battery.
- Li-po battery has less weight
- Li-po battery has High discharging capacity
- Li-po battery can be given required shape

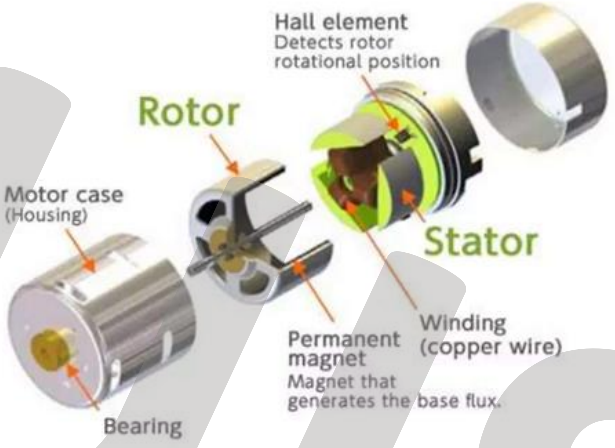


The seven main things that shorten LiPo battery life are:

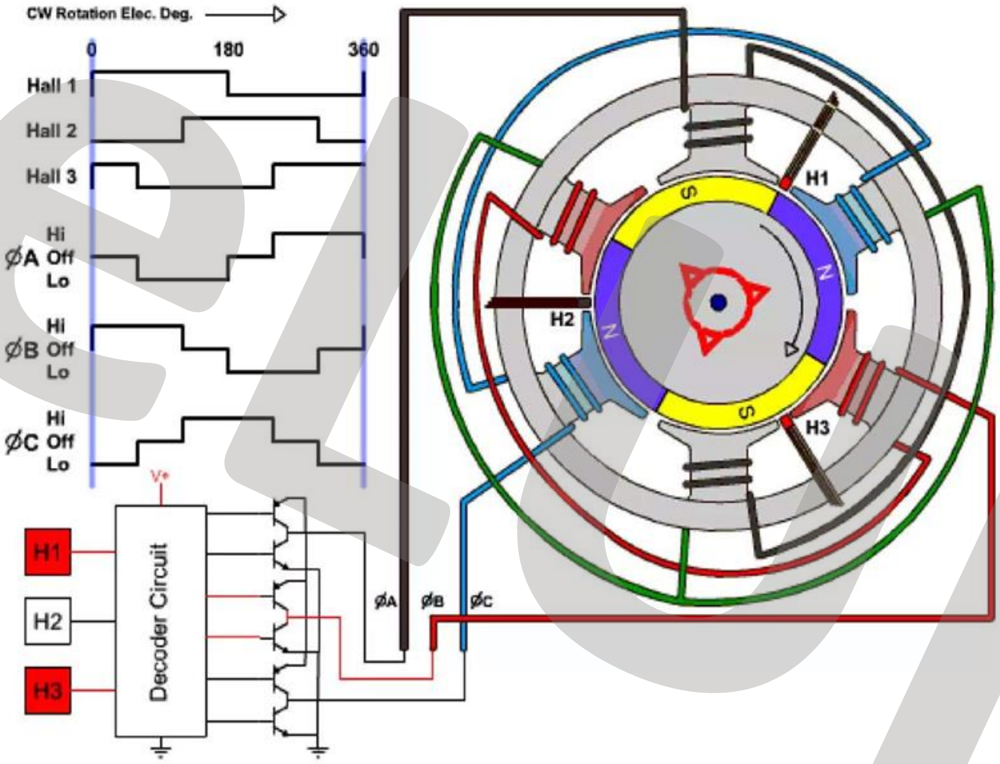
- Heat
- Leaving a lipo fully charged for several days
- Over discharging (voltage & current)
- Over charging (voltage & current)
- Inadequate balancing
- Improper storage voltage (more on that shortly)
- Physical damage (dropping, over tightening straps, prying cells apart, using too much/too strong velcro etc.)

Brushless DC motor:

- Like a brushed motor, a brushless motor works by alternating the polarity of windings inside the motor.
- It is essentially an inside out brushed motor, which eliminates the need for brushes.
- In a brushless DC motor, the permanent magnets are fitted to the rotor, with the electromagnets on the stator.
- An electronic speed controller (ESC) regulates or 'commutates' the charge to the electromagnets in the stator, to enable the rotor to travel through 360-degrees.



Brushless DC motor:



Brushless DC motor:

Advantages:

Long lifespan: Brushless DC motors don't have brushes, which means they require less maintenance than their brushed counterparts.

Efficiency: The lack of brushes means that no speed is lost, making brushless DC motors a little more efficient, typically 85-90% compared with their brushed counterparts at a typical 75-80% efficiency.

Quiet operation: Due to the lack of brushes, brushless motors run extremely quietly and have particularly smooth operation. This is especially useful for applications that require such properties, such as patient hoists.

Disadvantages:

Requires a controller: Brushless DC motors need to be wired to an electronic speed control (ESC), to enable current to flow to the electromagnets.

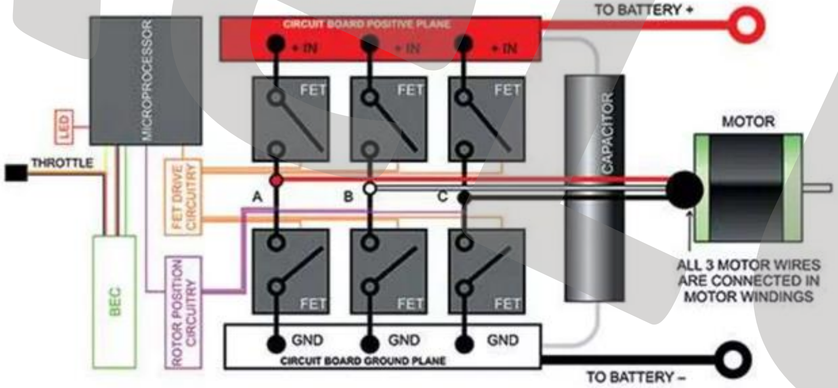
Cost: Due to the requirement for a controller, brushless DC motors can be more expensive.

Types of BLDC motors:

- NEMA Frame BLDC motors
- Gimbal BLDC motors
- Single pole BLDC motors
- Outer Runner BLDC motors

Electronic Speed Controller (ESC):

Electronic speed controllers (ESC) are the electronic circuits that regulate the speed of the DC motors. It also provides dynamic braking and reversing options.



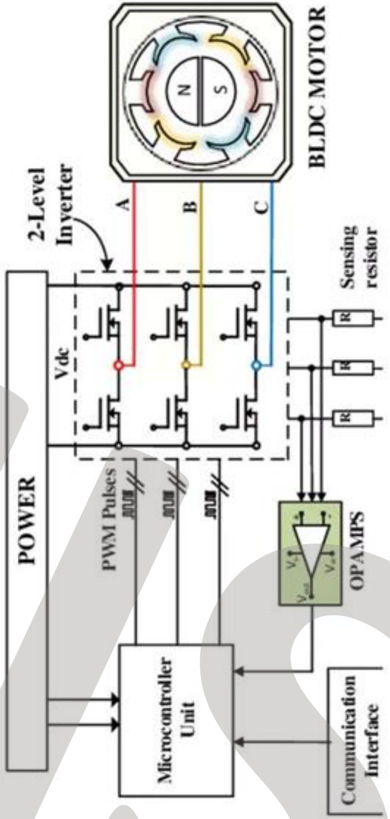
Applications of ESC:

- Electric cars
- Electric bicycles
- Electric aircraft
- Cars
- Helicopters
- Airplanes
- Boats
- Quadcopters
- ESC Firmware

Electronic Speed Controller (ESC):

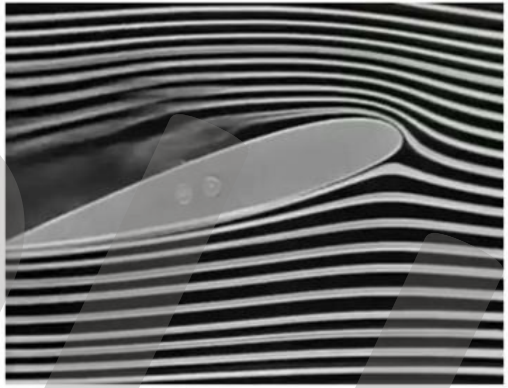
The Function of Electronic Speed Control:

- An ESC or electronic speed control mainly follows a speed reference signal to change the speed of a switching network of field-effect transistors.
- The motor speed can be changed by changing the switching frequency or the duty cycle of the transistors.
- For BLDC motors, different kinds of speed controls are necessary because this motor speed can be controlled by changing the voltage on its armature.
- This kind of motor needs a diverse operating rule like the motor speed can be changed by varying the timing of pulses for current transmitted to the different motor windings.



Propellers:

- Propellers are devices that transform rotary motion into linear thrust.
- Drone propellers provide lift for the aircraft by spinning and creating an airflow, which results in a pressure difference between the top and bottom surfaces of the propeller.
- This accelerates a mass of air in one direction, providing lift which counteracts the force of gravity.



Propellers:

- Propellers for multirotor drones such as Hexacopter, Octocopter and Quadcopter propellers, are arranged in pairs, spinning either clockwise or anti-clockwise to create a balance.
- Varying the speed of these propellers allows the drone to hover, ascend, descend, or affect its yaw, pitch and roll.
- Propeller speeds are varied by changing the voltage supplied to the propeller's motor, a process that is handled by an Electronic Speed Controller (ESC).

Propellers:

- Drone propellers can be constructed with two, three, or four blades.
- Propellers with more blades provide greater lift due to more surface area moving through the air per rotation, but are more inefficient due to increased drag.
- Smaller drones with limited battery life are best suited to propellers with fewer blades

Materials used for propellers:

- Carbon fiber
- Plastic

Disadvantages:

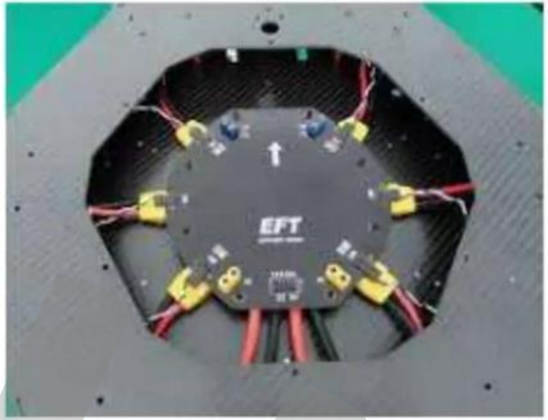
- Cost is High.
- Low flexibility.
- Absorption of impact is less.

Purpose of using carbon Fiber:

- The increased stiffness of carbon fiber propellers, although providing less durability, decreases vibration thus improving the flight performance of the drone and making it quieter.
- Carbon fiber is also lighter than plastic, allowing weight savings.

Power Distribution Board (PDB):

- PDB's essentially distribute the power from the battery to other components of the drone.
- It is usually connected to power module which reduces the incoming voltage to 5V
- It directly gives voltage supply to ESCs, Power Module, Pump Motor etc.



Power Module

- Power module is an electronic component that decreases the voltage to 5V
- Once voltage is 5V it is then transferred to Flight Controller
- Also called PMU (Power Management Unit)

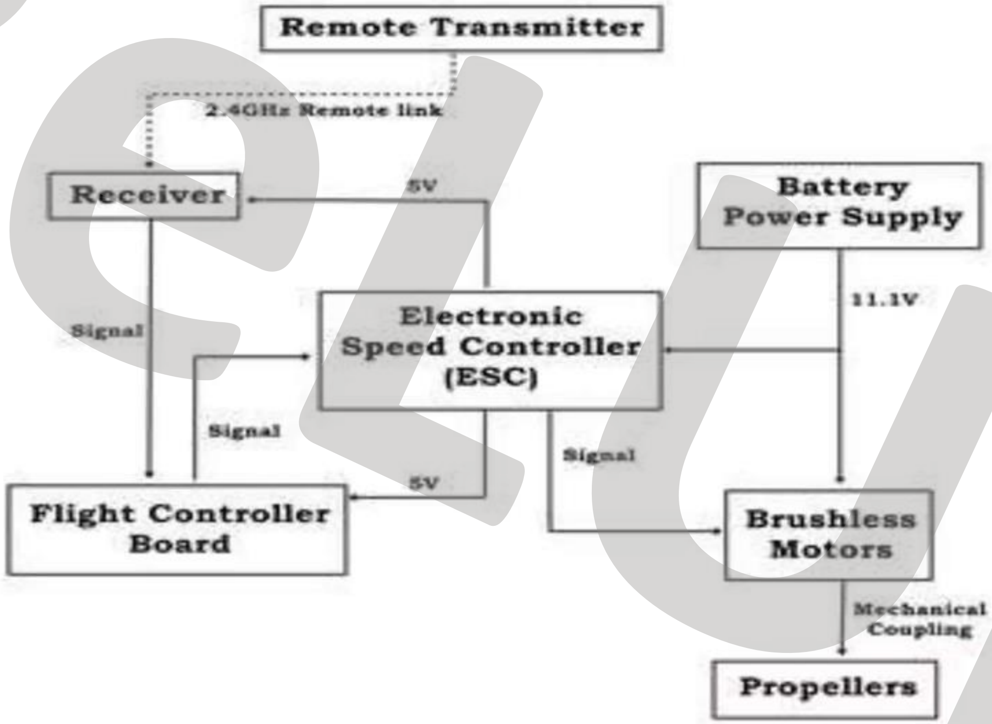
Transmitter

- 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 the drone being remotely controlled.
- In other words, it's the device that translates the pilot's commands into the movement of the multirotor.

Receiver

- The receiver on a drone is an electronic device that uses built-in antennas to receiver radio signals from the drone controller.
- But the receiver doesn't just receive signals from the drone controller. It also interprets the signals and converts them into alternating current pulses.
- This information is then sent to the flight control board, or flight controller, which puts the information into action by controlling the drone as indicated by the original radio signals.

Transmitter Receiver Block Diagram



Telemetry:

- Drone telemetry is data gathered about the aircraft and its surroundings that is sent back to the operator or ground control station (GCS).
- It is a two way communication.
- 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.

Global Positioning System (GPS):

- The GPS module provides the navigational data (longitude, latitude and elevation) to the Controller.
- This module assists the controller in recognizing the taken path and safely return to the initial point in case of lost connection.
- Elevation is taken using alti-meter in fc (From ground)

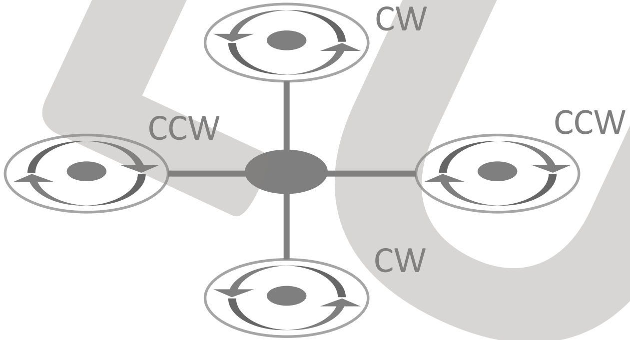
Landing Gears:

- Landing gears are not required for small drones. However, bigger drones need a landing gear to avoid any damage while landing.
- The requirement of landing gear varies with functionality of the drone.

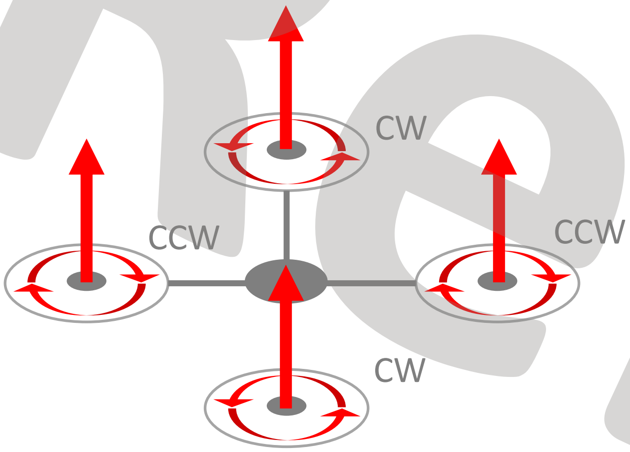
How it works

Working principle (quad-copter example)

- Quad-copters use two pairs of identical fixed pitched propellers (hex-copter: 3 pairs, etc.)
    - Two clockwise (CW)
    - Two counter-clockwise (CCW)
- These use independent variation of the speed of each rotor to achieve control
    - By changing the speed of each rotor it is possible to specifically generate a desired total thrust

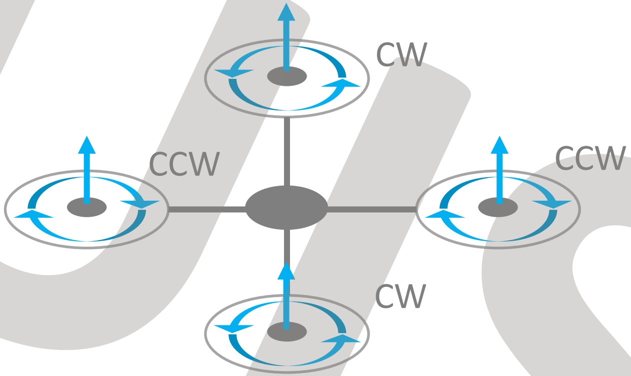


Working principle



TAKE-OFF

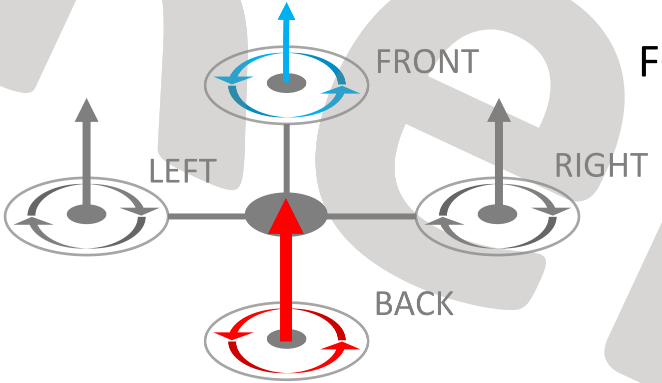
LANDING



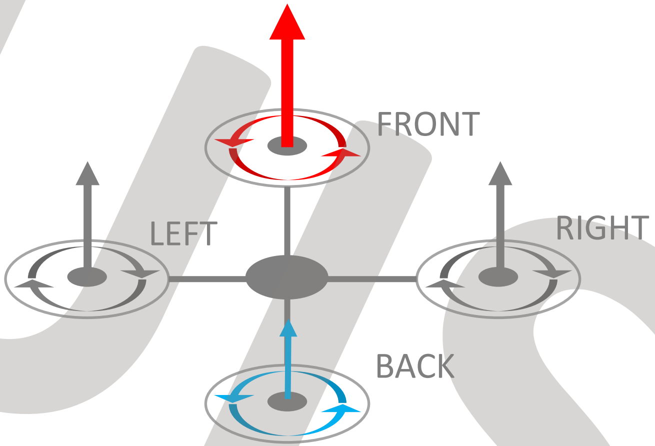
RED – High speed motor
BLUE – Low speed motor

Working principle

FORWARD

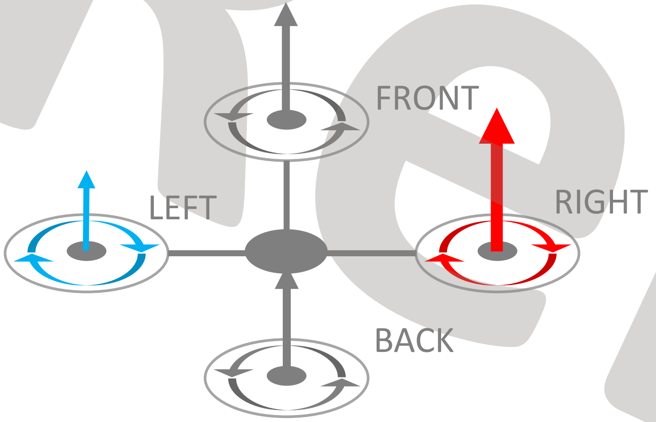


BACKWARD

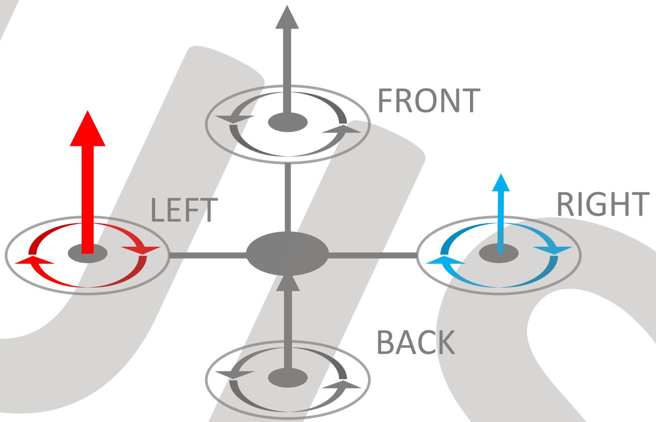


RED – High speed motor
BLUE – Low speed motor

Working principle



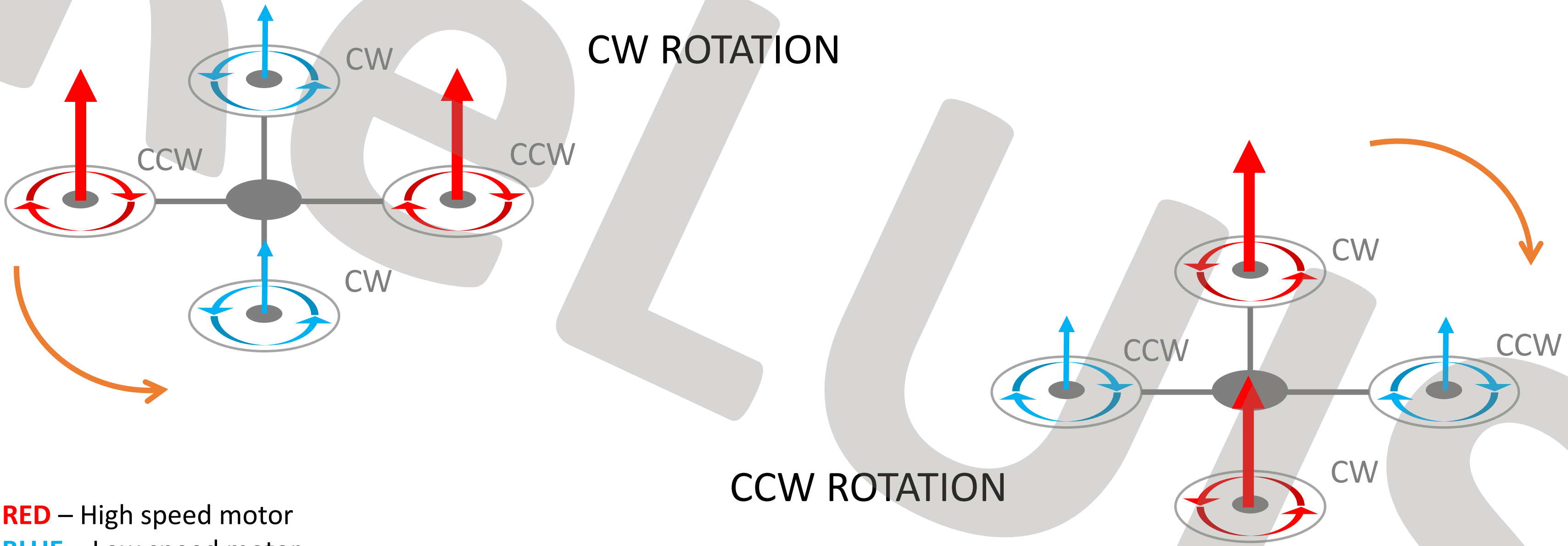
LEFT



RIGHT

RED – High speed motor
BLUE – Low speed motor

Working principle

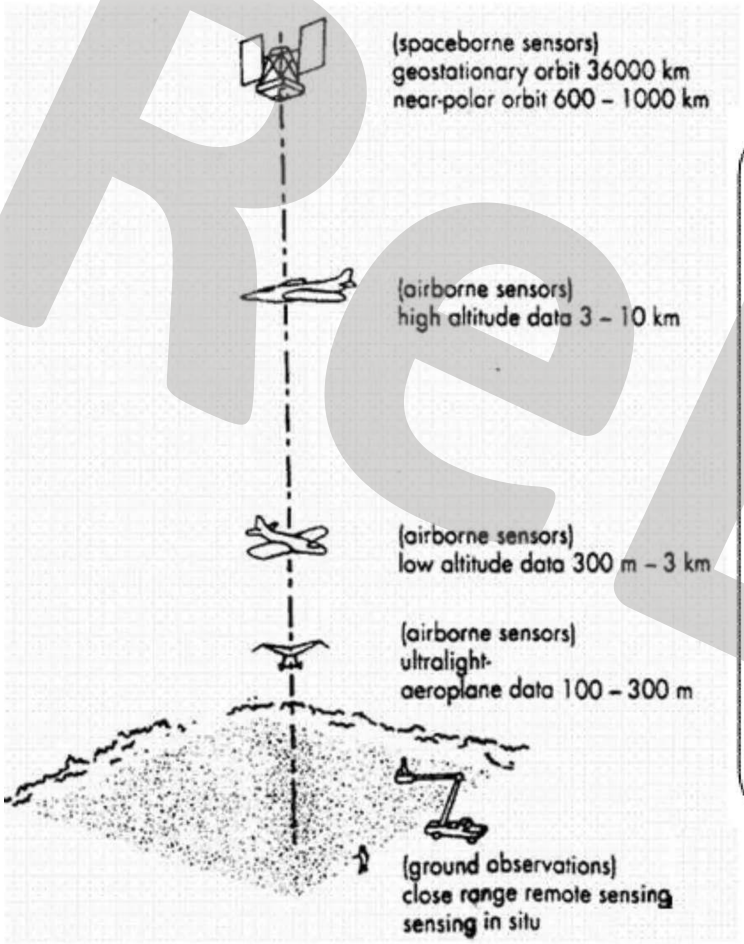


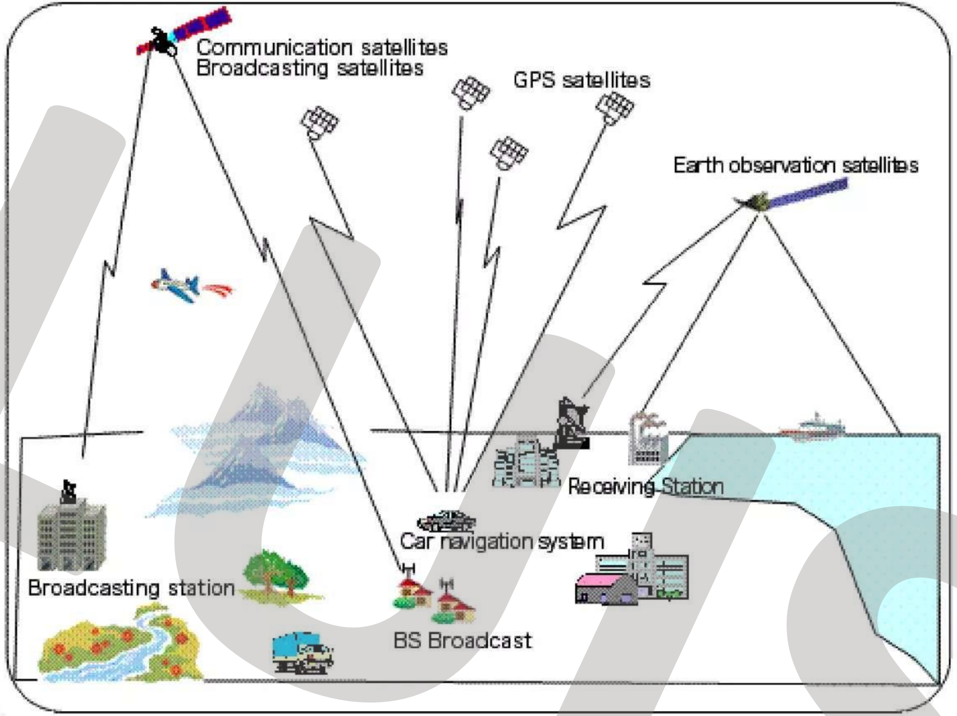
RED – High speed motor
BLUE – Low speed motor

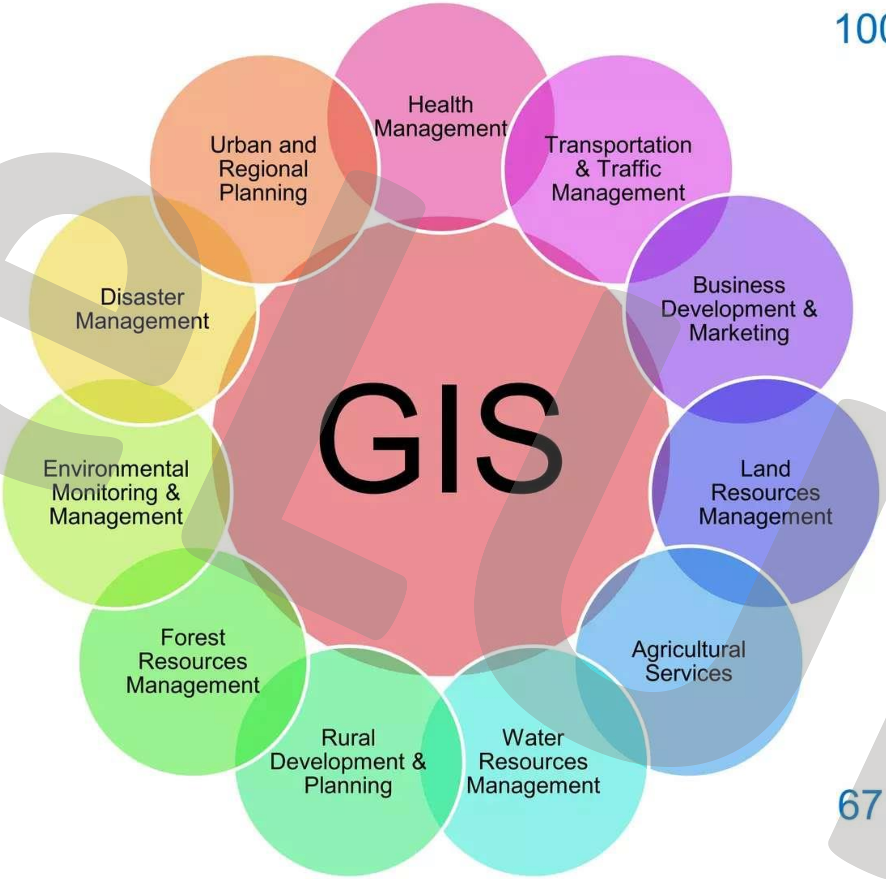
Photogrammetry

Topics

1. Introduction
2. Principles of Photogrammetry
3. Types of Aerial Photographs
4. Geometry of Vertical Aerial Photograph
5. Scale & Height Measurement
6. Fundamentals of Stereoscopy
7. Parallax Measurement


(spaceborne sensors)
geostationary orbit 36000 km
near-polar orbit 600 – 1000 km
(airborne sensors)
high altitude data 3 – 10 km
(airborne sensors)
low altitude data 300 m – 3 km
(airborne sensors)
ultralight-
aeroplane data 100 – 300 m
(ground observations)
close range remote sensing
sensing in situ


Communication satellites
Broadcasting satellites
GPS satellites
Earth observation satellites
Receiving Station
Car navigation system
Broadcasting station
BS Broadcast



1000 Applications & Uses

67 Major Applications

Remote Sensing

Remote Sensing is the acquisition of information about an object or phenomenon without making physical contact with the object and thus in contrast to on site observation.

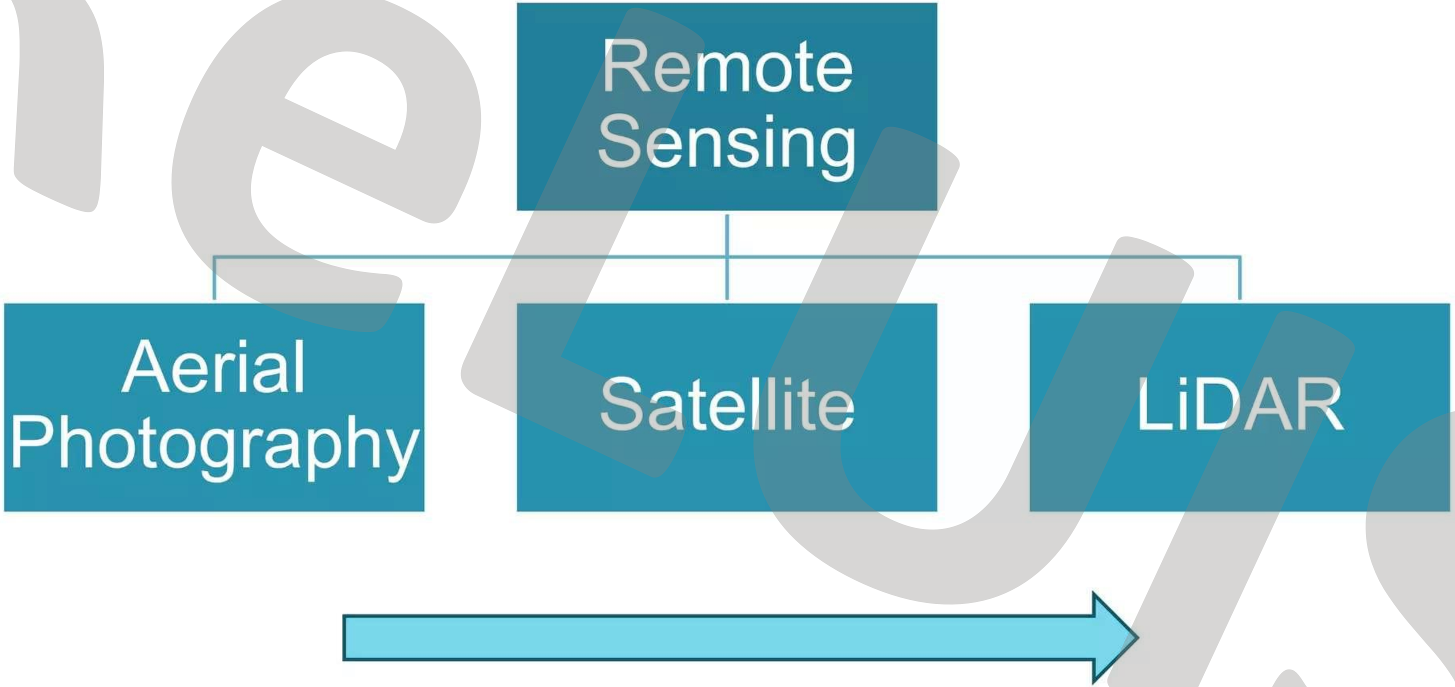
Remote Sensing

"The acquisition of physical data of an object without touch or contact"
- Lintz and Simonett, 1976

"The observation of a target by a device some distance away"
- Barrett and Curtis, 1982

"The use of electromagnetic radiation sensors to record images of the environment, which can be interpreted to yield useful information" **- Curran, 1985**

"The use of sensors, normally operating at wavelengths from the visible to the microwave, to collect information about the Earth's atmosphere, oceans, land and ice surfaces" **- Harris, 1987**


Remote Sensing
Aerial Photography
Satellite
LiDAR

Remote Sensing

Device to sample and measure radiation

↓

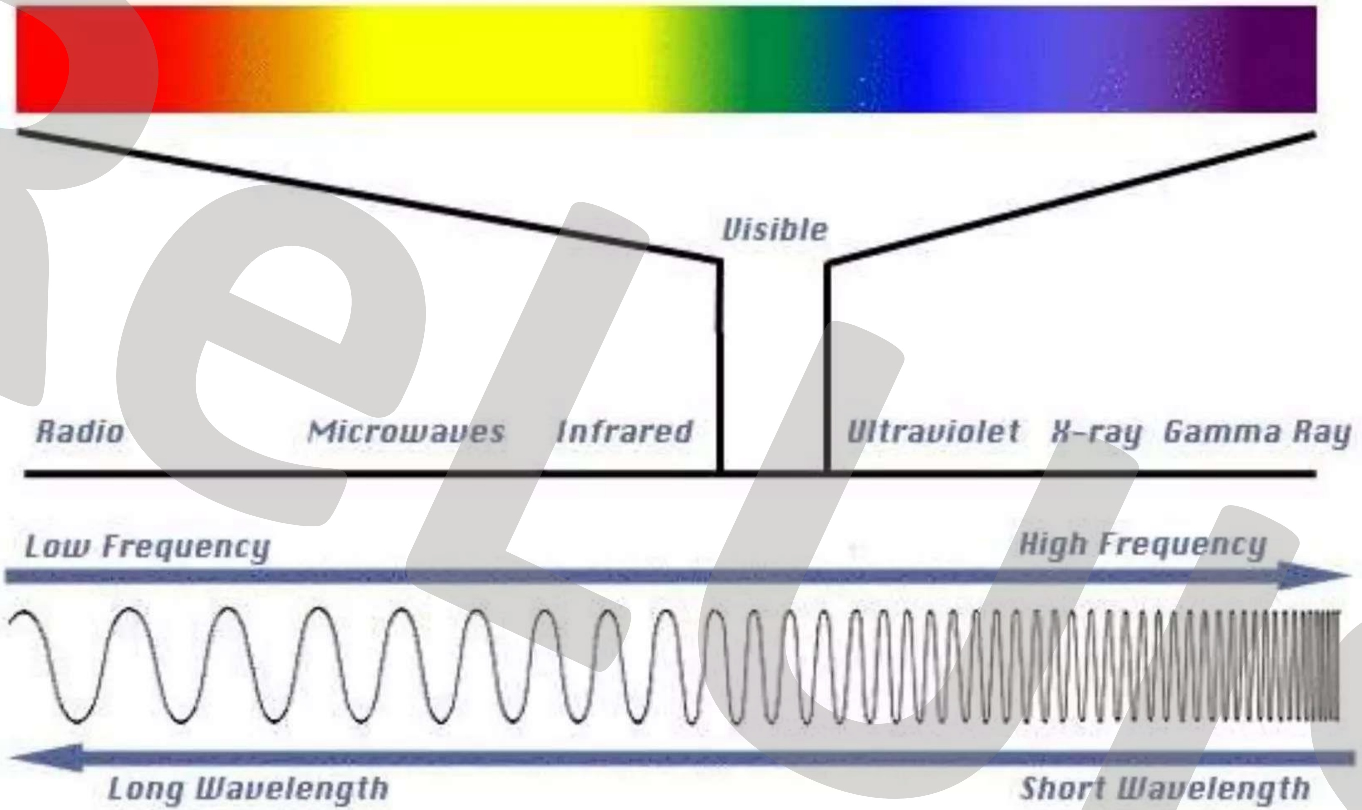
Medium = electromagnetic radiation

↓

Target is the terrestrial environment (atmosphere, oceans, land surface)

LISS – III
Camera

Device to sample and measure radiation (sensor)



Medium = Electro Magnetic Radiation (EMR)

Introduction to Photogrammetry

Definition of Photogrammetry:
The art, science, and technology of obtaining information about physical objects and the environment by photographic and electromagnetic images.

Categories:

1. **Metrical Photogrammetry:** obtaining measurements from photos from which ground positions, elevations, distances, areas, and volumes can be computed and topographic or planimetric maps can be made.
2. **Photo Interpretation:** evaluation of existing features in a qualitative

Types of Photogrammetry

1. **Aerial** – series of photographs of an area of terrain in sequence using a precision camera.
2. **Terrestrial** – photos taken from a fixed and usually known position on or near the ground with the camera axis horizontal or nearly so.
3. **Close range** – camera close to object being observed. Most often used when direct measurement is impractical.

Photogrammetry for Engineering

Photogrammetry is the process of measuring images on a photograph.

Modern Photogrammetry also uses radar imaging, radiant electromagnetic energy detection and x-ray imaging – called ***Remote Sensing*.**

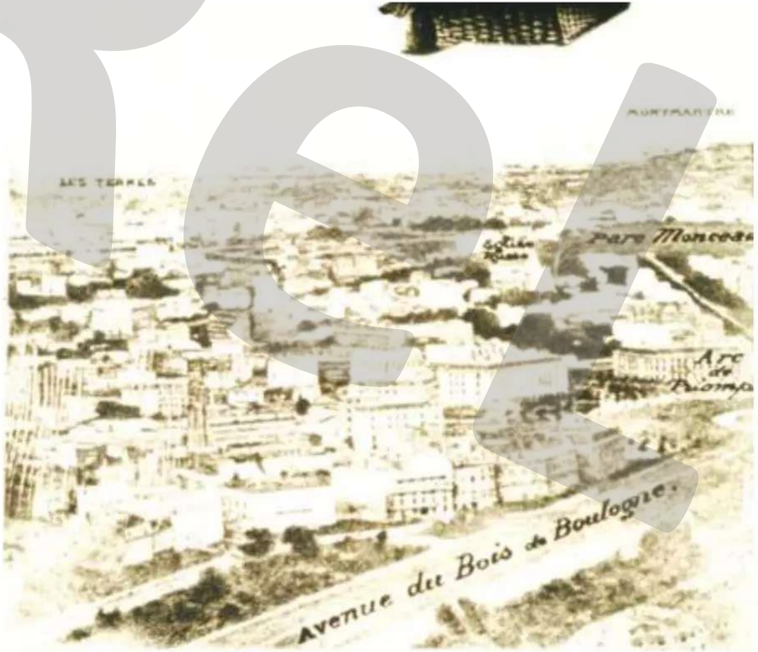
Origins of Remote Sensing

Remote Sensing began with Aerial Photography

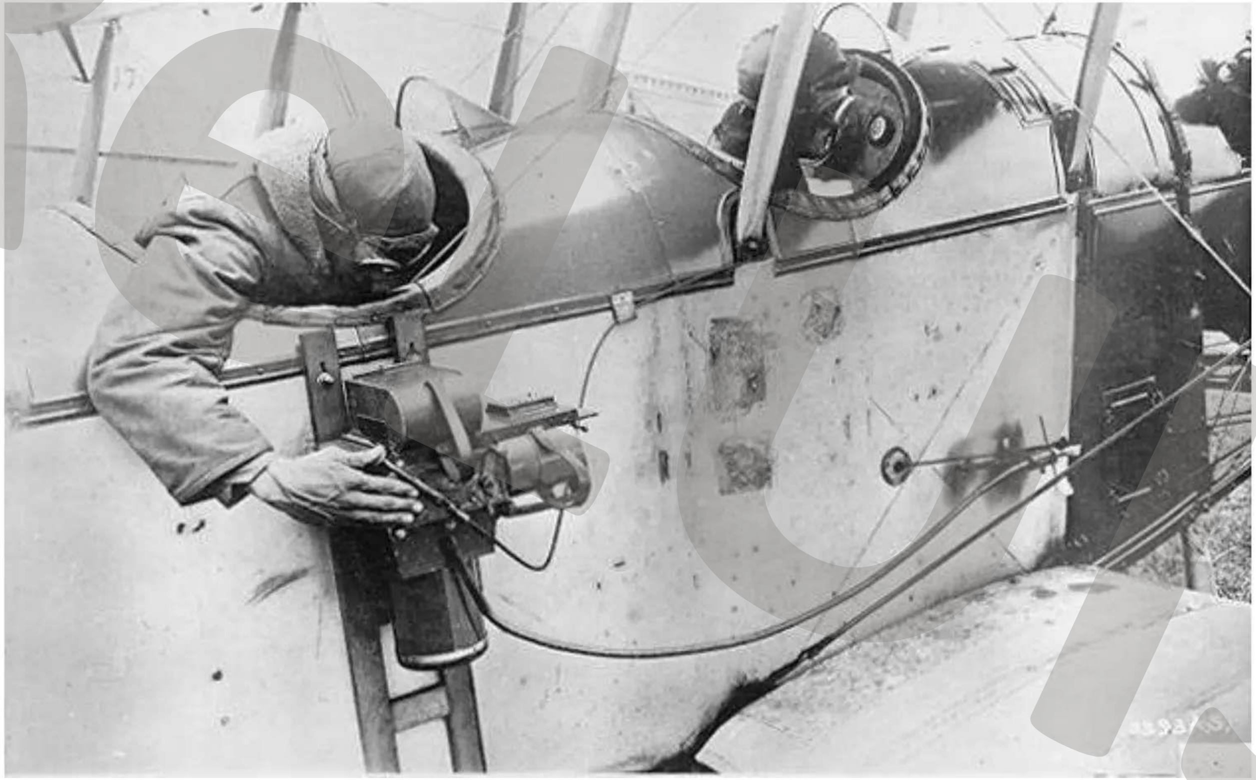
First photographs taken in 1839

In1858 Gasper Felix Tournachon "Nadar" takes photograph of village of Petit Bicetre in France from a balloon

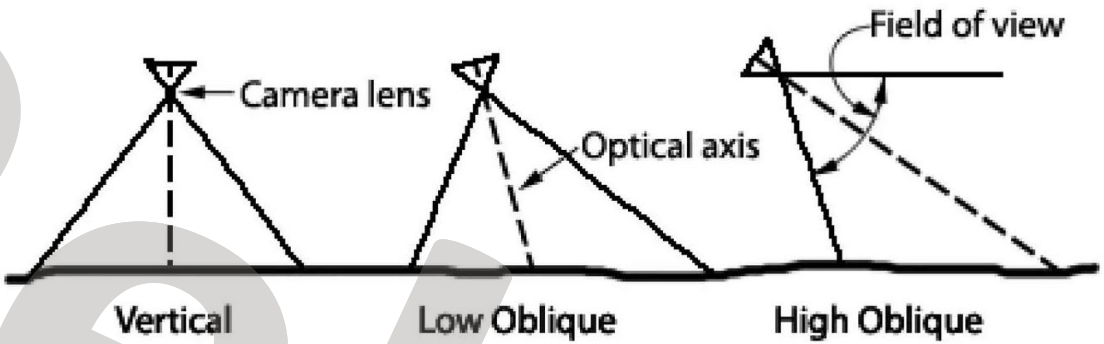
Paris by Nadar, circa 1859   Boston by Black and King (1860



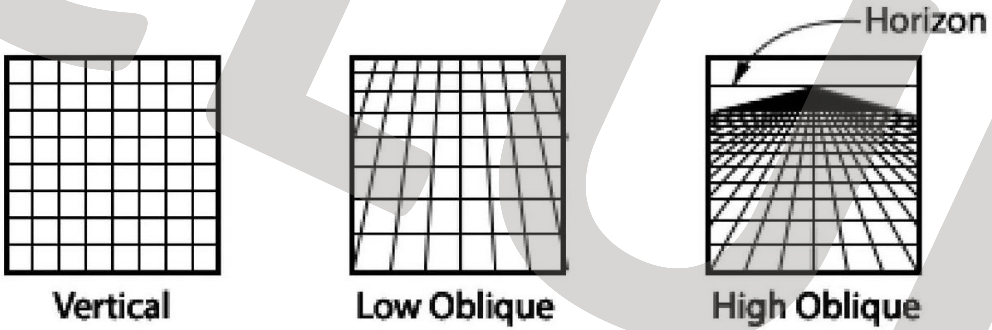
World War One was a major impetus to development of aerial photography



Types of Aerial Photographs



Camera orientation for various types of aerial photographs



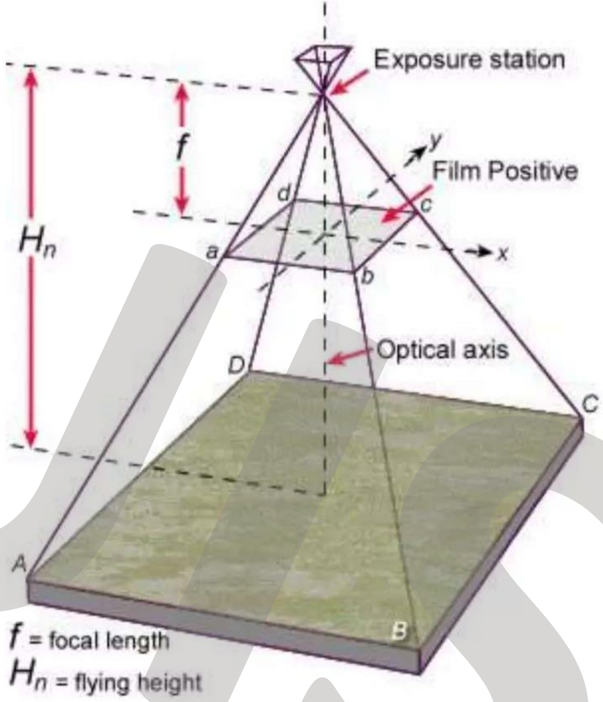
How a grid of section lines appears on various types of photos.

Vertical Aerial Photograph

Vertical is most important as it has minimum distortion and can be used for taking measurements.

Characteristics:

- Tilt <= 3^0 from the vertical
- Scale is approximately constant throughout the photo
- Most common format is 9” x 9” photograph

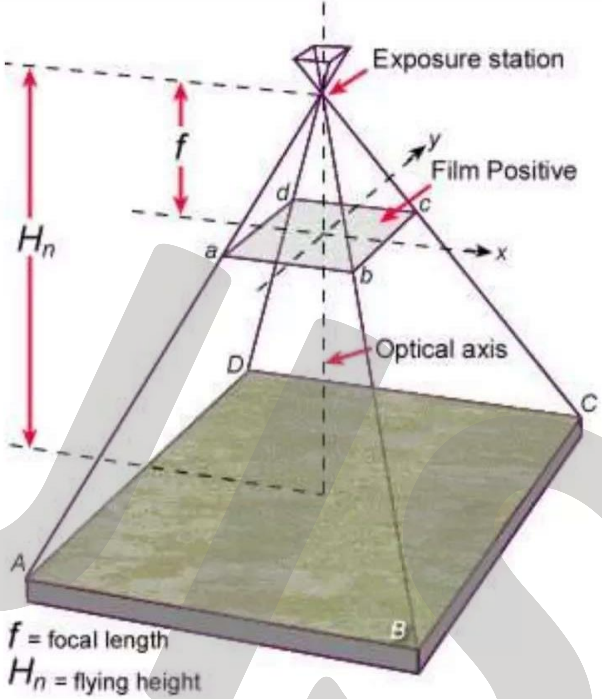


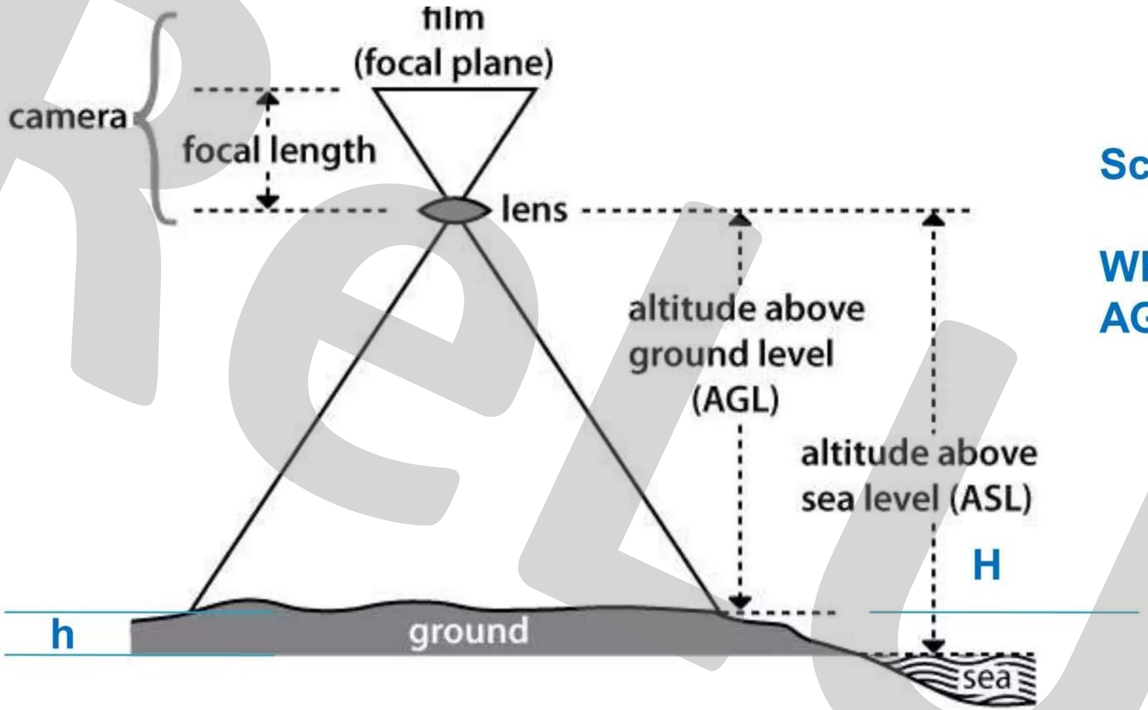
Scale Measurement

If you know focal length of camera and height of aircraft above the ground you can calculate the scale of the photograph.

Scale = f/H-h

f = focal length (distance from centre of lens to film surface)
H = flying height of aircraft above sea level
h = height of ground above sea level





Scale = focal Length/AGL

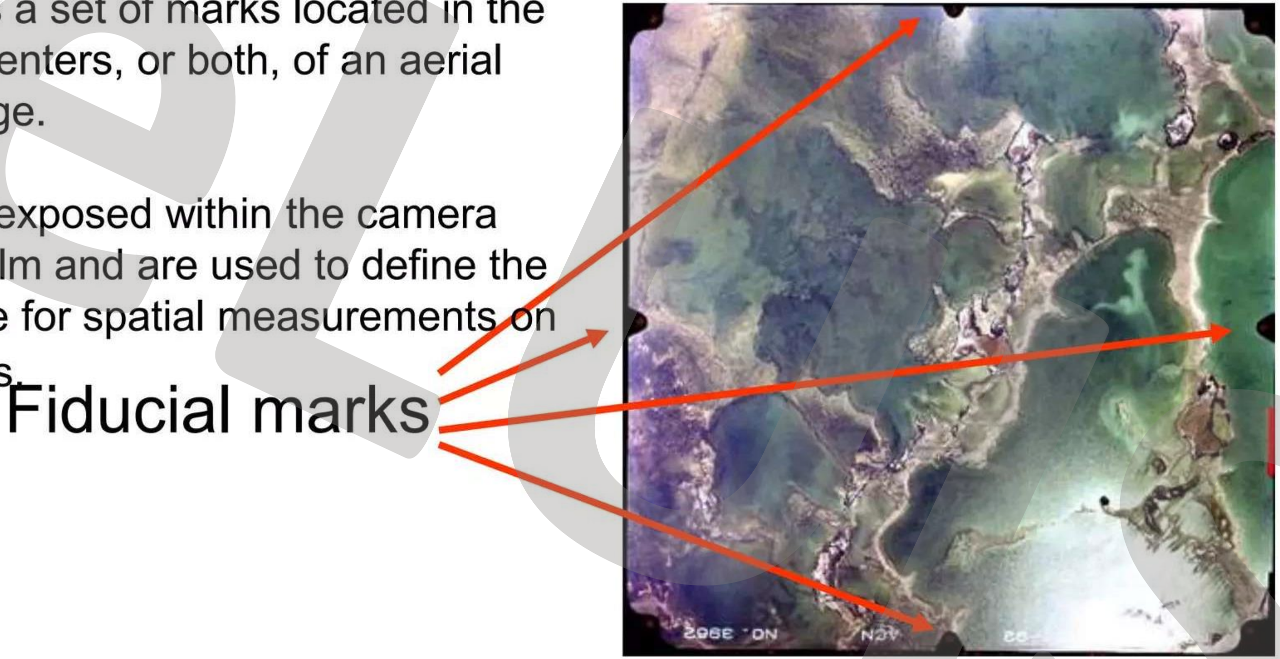
Where
AGL = H-h

When you know the scale you can take 2-D measurements from a photograph (e.g. horizontal distance, horizontal area, etc.)

Terminology

Fiducial marks is a set of marks located in the corners or edge-centers, or both, of an aerial photographic image.

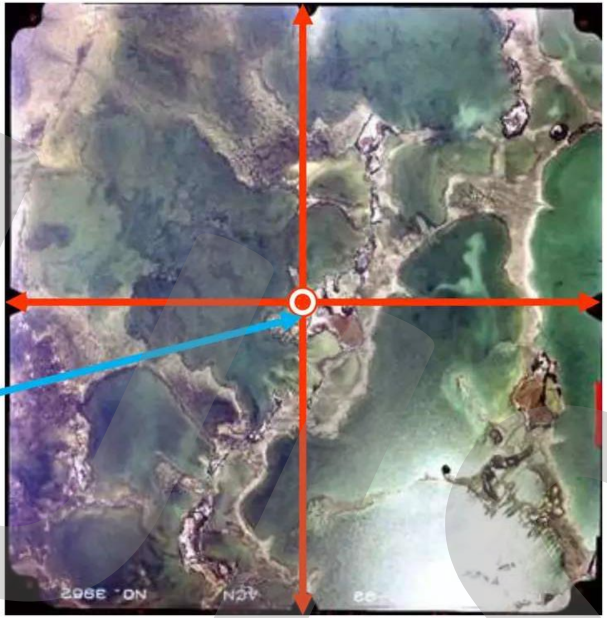
These marks are exposed within the camera onto the original film and are used to define the frame of reference for spatial measurements on aerial photographs.



Terminology

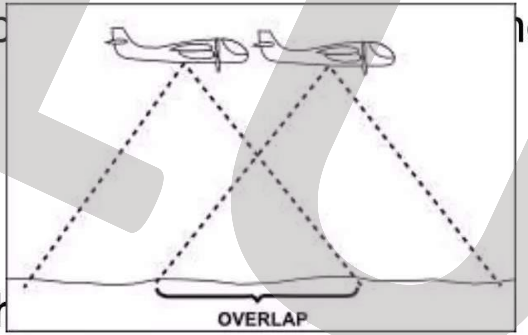
Opposite fiducial marks connected, intersect at approximately the image center or principal point of the aerial photograph.

The principal point is the geometric center of the photograph



Flight Planning

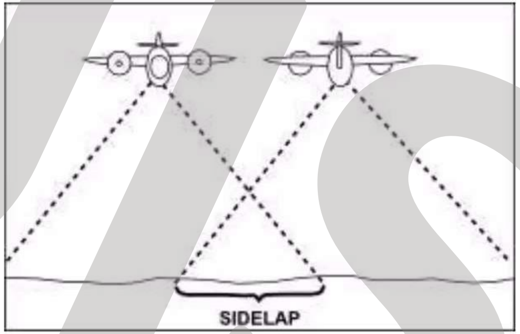
Aerial photo projects for all mapping and most image analyses require that a series of exposures be made along each of the multiple flight lines.

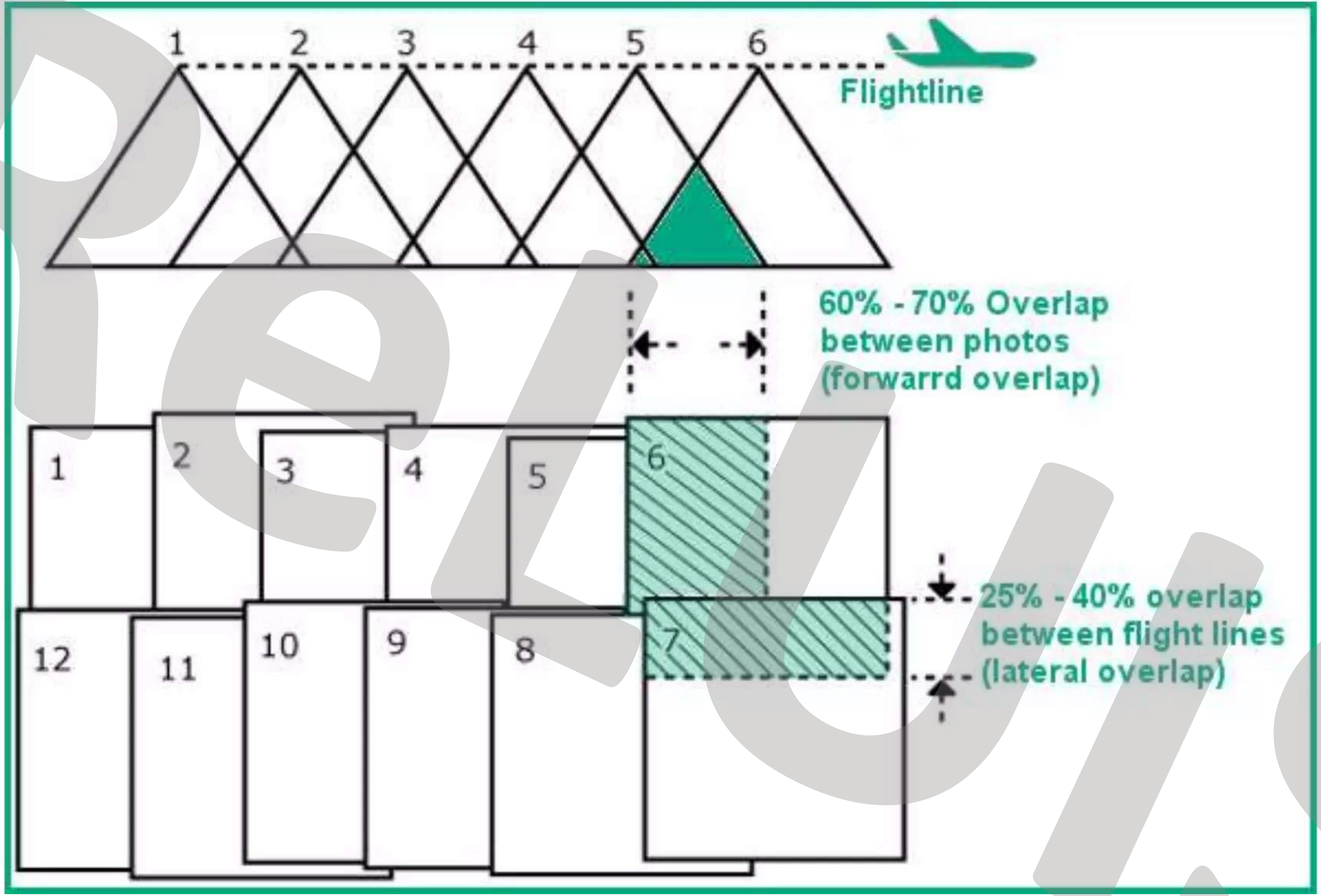
To guarantee stereoscop 

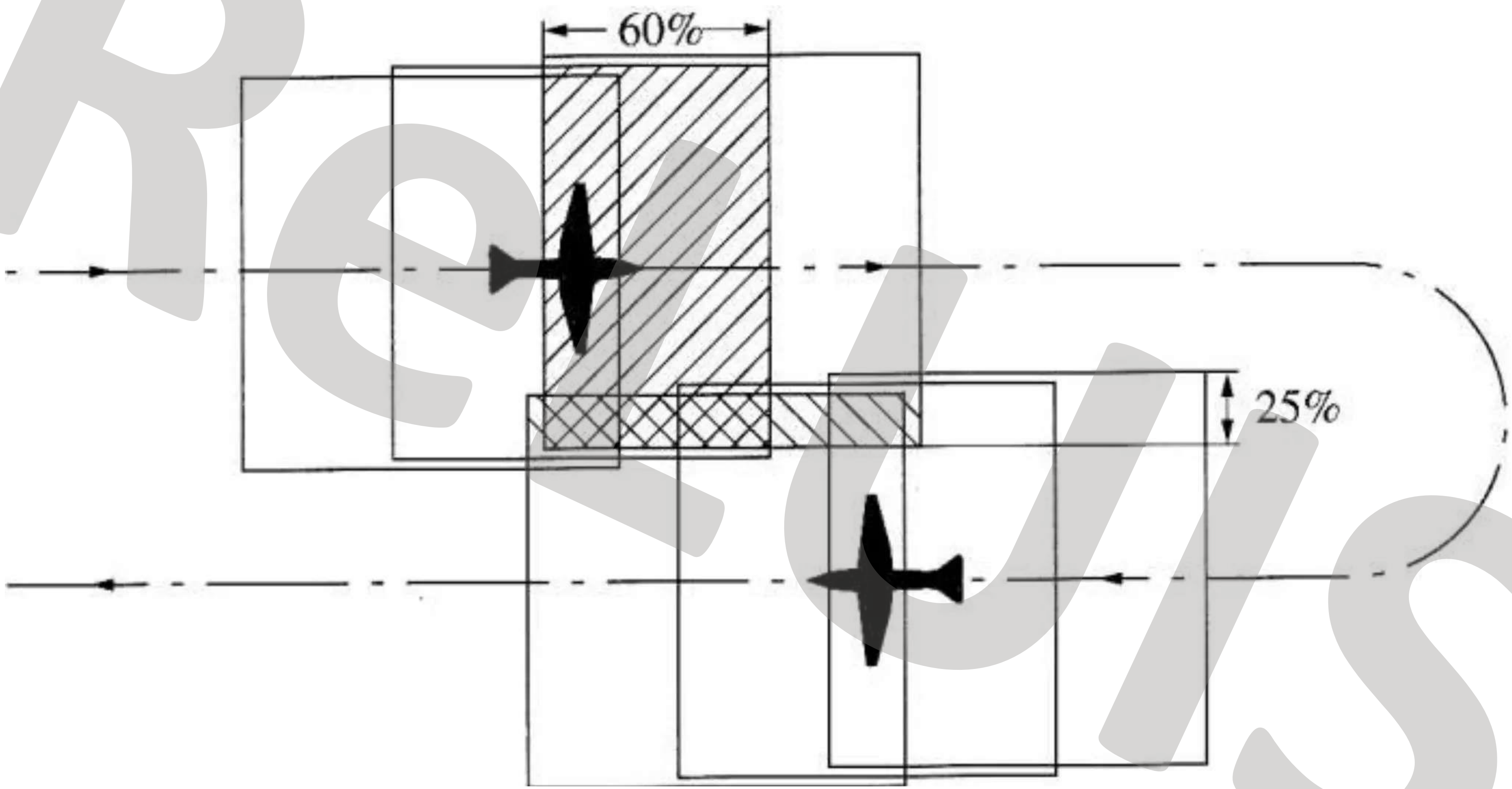
hout the site, the photographs must overlap

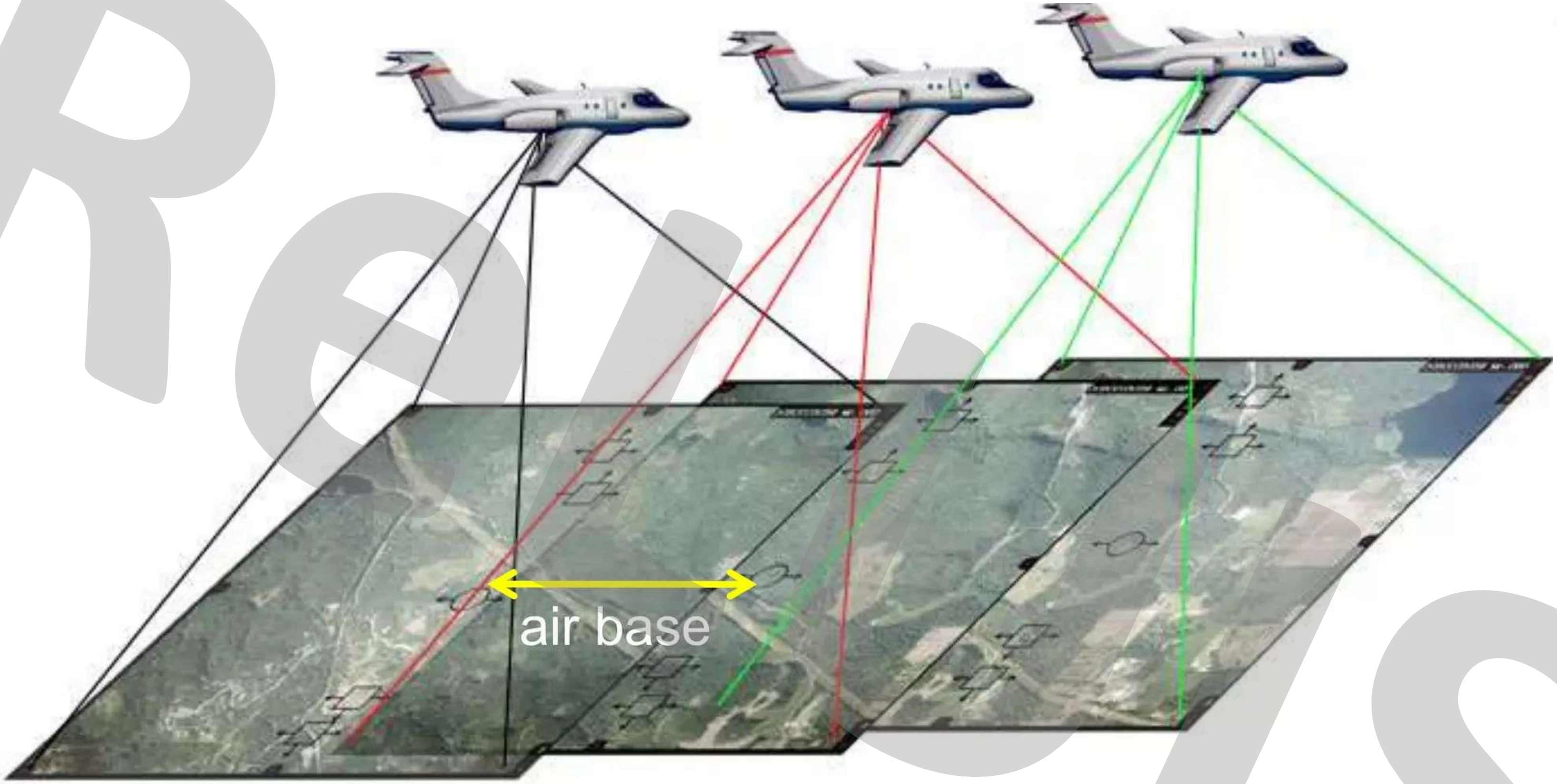
a) **in the line of flight**
(Overlap)
needed for parallax

a) **between adjacent fligh**
(Sidelap)
to avoid missing bits




1
2
3
4
5
6
Flightline
60% - 70% Overlap
between photos
(forwarrd overlap)
1
2
3
4
5
6
12
11
10
9
8
7
25% - 40% overlap
between flight lines
(lateral overlap)


60%
25%



Distance between principal point of adjacent photographs is known as the **"air base"**

Fundamentals of Stereoscopy

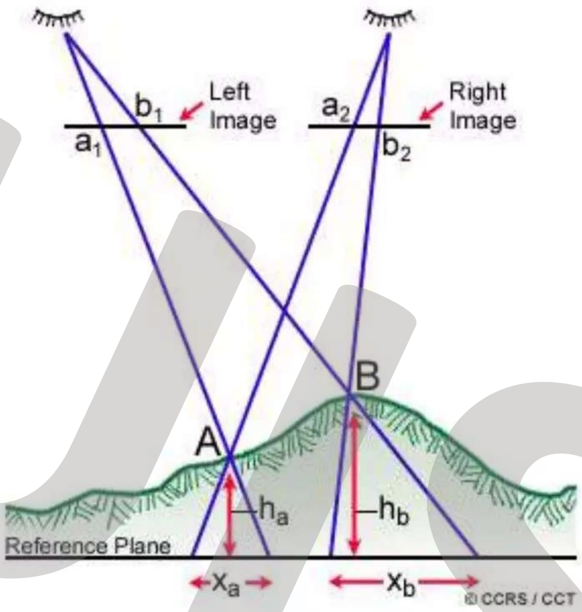
Stereoscopy, sometimes called stereoscopic imaging, is a technique used to enable a three-dimensional effect, adding an illusion of depth to a flat image.

In aerial photography, when two photographs overlap or the same ground area is photographed from two separate position forms a **stereo-pair**, used for three dimension viewing. Thus obtained a pair of
stereoscopic photographs or images can be viewed stereoscopically to determine parallax and stereo/3D viewing

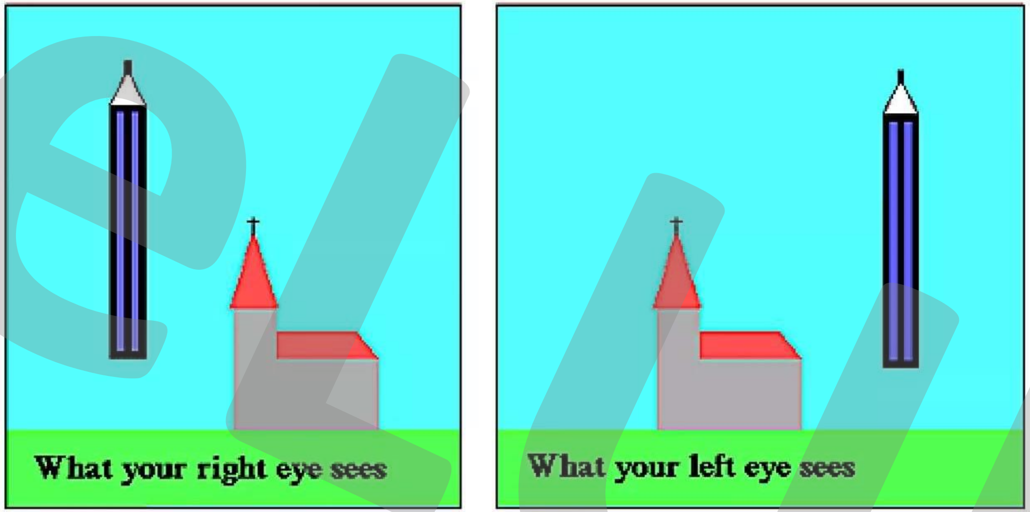
Parallax Measurement

Parallax:
The displacement of an object caused by a change in the point of observation is called parallax.

Stereoscopic parallax is caused by taking photographs of the same object but from different points of observation.



Parallax

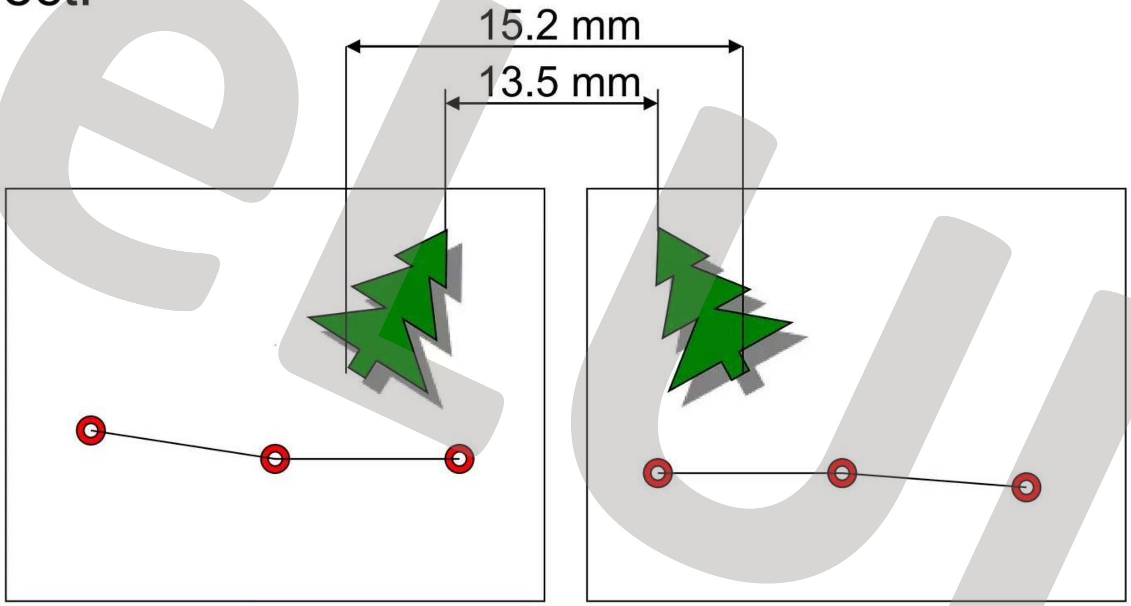


Pencil is very displaced because it is close to observe
Church is less displaced because it is further away

Stereoscopic parallax

The same principle can be used to find height of objects in stereopairs of vertical aerial photographs

- **Differential Parallax** is the difference between the stereoscopic parallax at the top and base of the object.



dP = 15.2mm – 13.5mm = 1.7 mm

Parallax Measurement

$$\text{Height of object} = \frac{H \cdot dP}{P + dP}$$

H = height of aircraft above ground
P = absolute parallax at base of object being measured*
dP = differential parallax

* For convenience the photo base length of a stereo pair is commonly substituted for absolute stereoscopic

Overview of the current European Aviation regulation for Aerial Robots

Summary

- EU set of regulations related with drones/UAS/aerial robots.
- Categories of operations: open, specific and certified.
- Requirements for the open and specific categories:
  - UAS Operator
  - UAS Manufacturer
- Introduction how to handle autonomous aerial operations (not supervised by a human pilot).
- Options for the integration of an aerial robot into the airspace.
- U-space introduction.

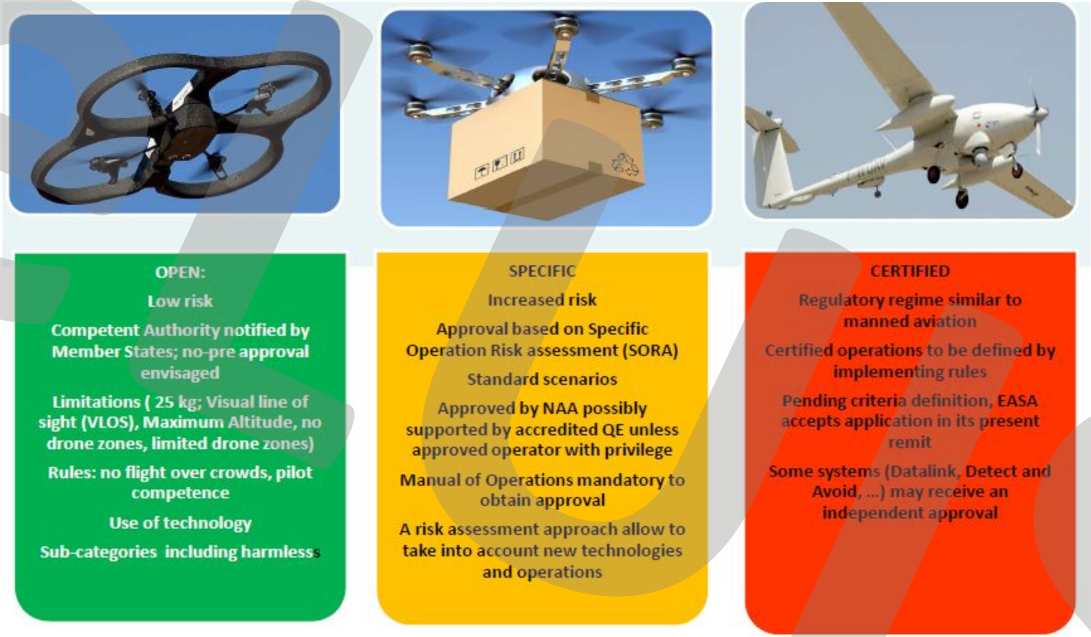
European Aviation regulations related with aerial robots

- To fly an aerial robot, this is not the only regulation that applies. For example:
  - Privacy
  - Environmental
  - …
- From the point of view of the European Aviation regulation, Aerial robots are considered unmanned aircraft systems or UAS
- The different aviation-related regulations that already come into force are:
  - EU Regulations 2019/947 and 2019/945
    - Framework for the safe operation of civil drones in the European skies
    - More information at: https://www.easa.europa.eu/en/domains/civil-drones
  - EU Regulations 2021/664, 2021/665, 2021/666
    - U-Space related regulation
    - More information at: https://www.easa.europa.eu/en/regulations/U-space
- EASA, in collaboration of the National Aviation Authorities (NAAs) is the EU entity that is in charge of developing and updating this regulation

Categories of operations

- EU Regulation 2019/947 and 2019/945 defines the following operations with UAS
  - Operation-centric
  - Risk-based approach

    Proportional

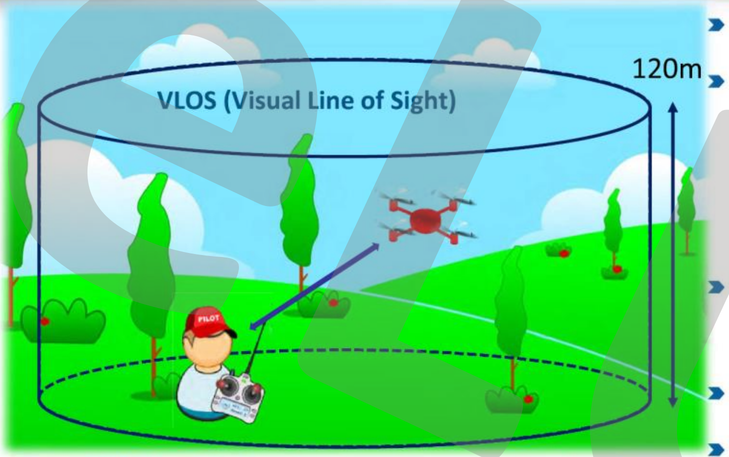


Categories of operations

- EU Regulation 2019/947 and 2019/945 defines the following operations with UAS
  - Important points to be remarked:
    - No distinction between professional and leisure activities
    - No distinction between experimental flights and aerial works
    - All this aviation regulation does not apply to indoor flights

Open category

Open category

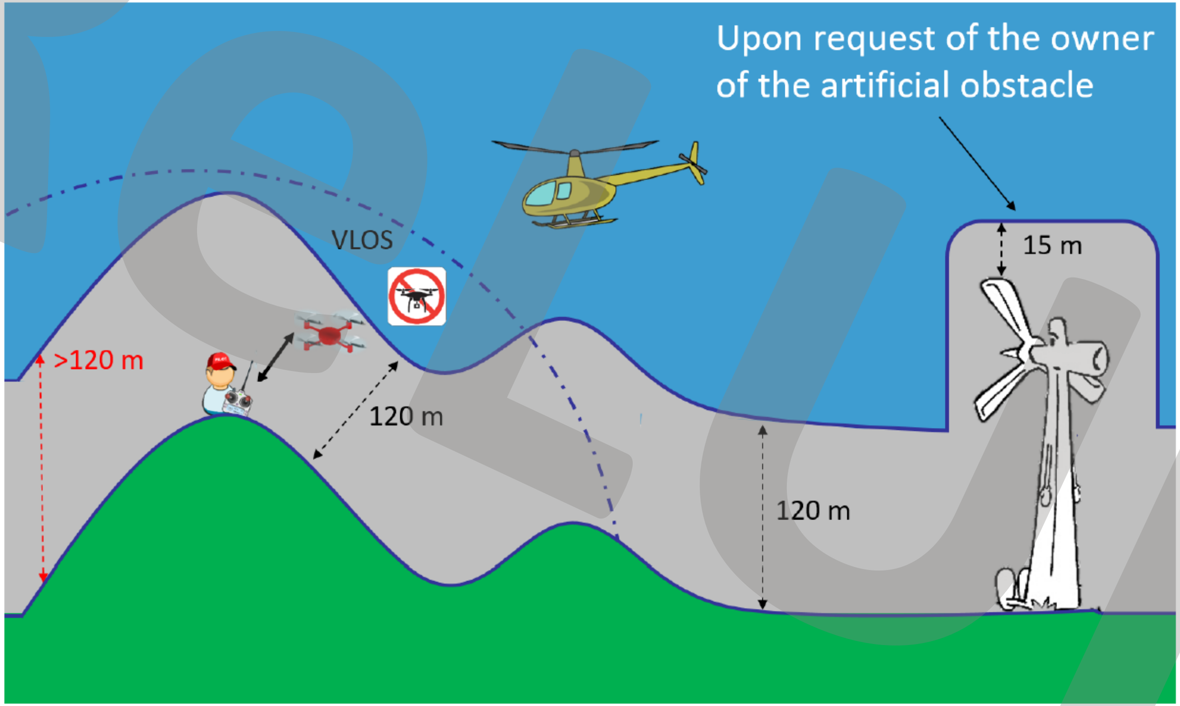


- MTOM < 25 Kg
- Remote pilot minimum age 16, unless supervised (it may be reduced to 12, no minimum age for toys)
- No carriage of dangerous goods
- No dropping of material
- No autonomous operations

- Additional limitations based on operational subcategory:
  - A1 fly over people — Privately built with MTOM<250g — C0, C1
  - A2 fly close to people — C2
  - A3 fly far from people — Privately built with MTOM<25kg — C3, C4

CE

Open category – What does it mean to fly below 120 meters?



Open category – Subcategories

Operation		Remote pilot competency (age according to MS legislation)	UAS				UAS operator registration
Subcategory	Area of operation (far from aerodromes, maximum height 120 m)		class	MTOM/ Joule (J)	Main technical requirements (CE marking)	Electronic ID/ geo awareness	
A1 Fly over people	You can fly over uninvolved people (not over crowds)	Read consumer info	Privately built	< 250 g	N/a	No	no
			C0		Consumer information, Toy Directive or <19 m/s, no sharp edges, selectable height limit		
		• Consumer info • online training • online test	C1	< 80 J or <900 g	Consumer information, <19m/s, kinetic energy, mechanical strength, lost-link management, no sharp edges, selectable height limit.	Yes + unique SN for identification	yes
A2 Fly close to people	You can fly at a safe distance from uninvolved people	• Consumer info • online training • online test • theoretical test in a centre recognised by the aviation authority	C2	< 4 kg	Consumer information, mechanical strength, no sharp edges, lost-link management, selectable height limit, frangibility, low-speed mode.		
A3 Fly far from people	You should: • fly in an area where it is reasonably expected that no uninvolved people will be endangered • keep a safety distance from urban areas	• Consumer info • online training • online test	C3	< 25 kg	Consumer information, lost-link management, selectable height limit, frangibility.		
			C4		Consumer information, no automatic flight	if required by zone of operations	
			Privately built		N/a		

Open category – Subcategories

Operation		Remote pilot competency (age according to MS legislation)	UAS				UAS operator registration
Subcategory	Area of operation (far from aerodromes, maximum height 120 m)		class	MTOM/ Joule (J)	Main technical requirements (CE marking)	Electronic ID/ geo awareness	
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			C0		Consumer information, Toy Directive or <19 m/s, no sharp edges, selectable height limit		
		• Consumer info • online training • online test	C1	< 8 <9	Consumer information		
A2 Fly close to people	You can fly at a safe distance from uninvolved people	• Consumer info • online training • online test • theoretical test in a centre recognised by the aviation authority	C2	< 4 kg	mechanical strength, no sharp edges, lost-link management, selectable height limit, frangibility, low-speed mode.	unique SN for identification	yes
A3 Fly far from people	You should: • fly in an area where it is reasonably expected that no uninvolved people will be endangered • keep a safety distance from urban areas	• Consumer info • online training • online test	C3	< 25 kg	Consumer information, lost-link management, selectable height limit, frangibility.		
			C4		Consumer information, no automatic flight	if required by zone of operations	
			Privately built		N/a		

Industrial products with closed configuration

Open category – CE marked aerial robots

- From January 2024: only CE marked UAS can be sold in Open category
- How to CE marked an aerial robot for the open category?
  - Easier way is to get in contact with a Notified Body. They will support you through the whole process
  - Check list of current Notified Bodies at: https://webgate.ec.europa.eu/single-market-compliance-space/#/notified-bodies/notified-body-list?filter=legislationId:159261,notificationStatusId:1

LEGISLATION Regulation (EU) 2019/945 on unmanned aircraft systems and on third-country opera...

Body type	Body Name	Country
NB 0197	TÜV Rheinland LGA Products GmbH	Germany
NB 0370	LGAI TECHNOLOGICAL CENTER, S. A.(Applus+)	Spain
NB 2031	ALTER TECHNOLOGY-TÜV NORD, S.A.U.	Spain
NB 2603	NavCert GmbH	Germany
NB 2806	CerTrust Kft.	Hungary

Open category – Subcategories

Operation		Remote pilot competency (age according to MS legislation)	UAS				UAS operator registration
Subcategory	Area of operation (far from aerodromes, maximum height 120 m)		class	MTOM/ Joule (J)	Main technical requirements (CE marking)	Electronic ID/ geo awareness	
A1 Fly over people	You can fly over uninvolved people (not over crowds)	Read consumer info	Privately built	< 250 g	N/a	No	no
			C0		Consumer information, Toy Directive or <19 m/s, no sharp edges, selectable height limit		
		…mer info …training …test	C1	< 80 J or <900 g	Consumer information, <19m/s, kinetic energy, mechanical strength, lost-link management, no sharp edges, selectable height limit.	Yes + unique SN for identification	yes
A2 Fly close to people	You can fly at a safe distance from uninvolved people	• Consumer info • online training • online test • theoretical test in a centre recognised by the aviation authority	C2	< 4 kg	Consumer information, mechanical strength, no sharp edges, lost-link management, selectable height limit, frangibility, low-speed mode.		
A3 Fly far from people	You should: • fly in an area where it is reasonably expected that no uninvolved people will be endangered • keep a safety distance from urban areas	• Consumer info • online training • online test	C3	< 25 kg	Consumer information, lost-link management, selectable height limit, frangibility.		
			C4		Consumer information, no automatic flight	if required by zone of operations	
			Privately built		N/a		

Prototypes

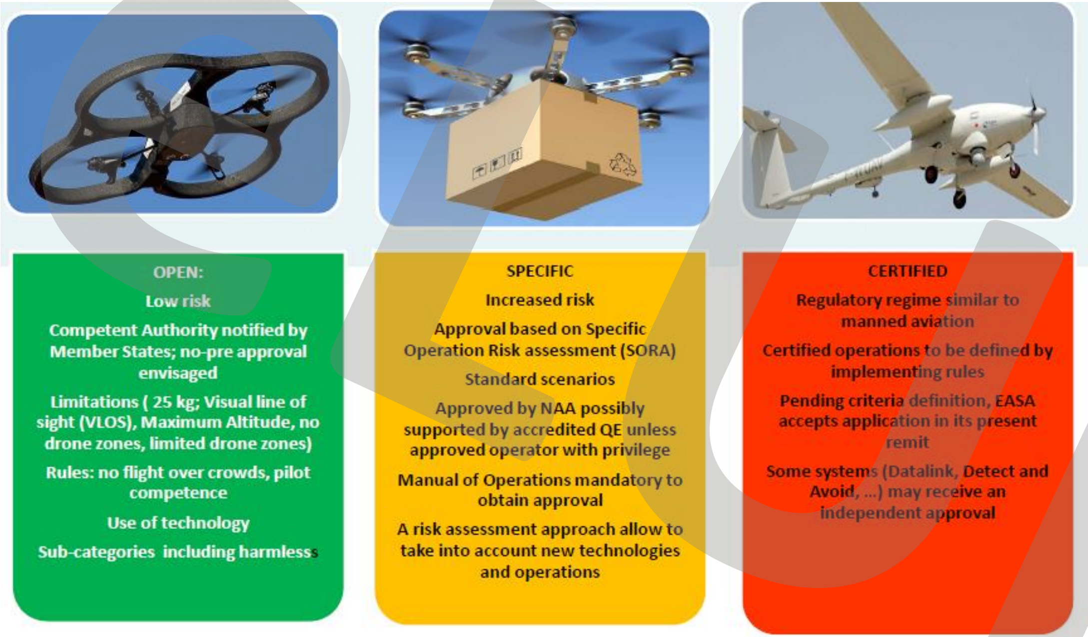
Open category – Summary

- Buy and fly concept
  - No interaction with the aviation authority
- Only VLOS operations
  - It is required to check that the airspace allows Open category operations
    - We suggest to start checking the webpage of your ANSP (Air Navigation Service Provider) or National Aviation Authority (NAA)
- Always below 120m
- MTOW not greater tan 25Kg (or less depending how close you intend fly to people)
- Not possible fully autonomous, non-supervised operations
  - But you can always execute autonomous functionalities with a “supervising” pilot

- If you plan to commercialize a product, then it is mandatory from January 2024 that your aerial robot is CE marked
- For prototypes, two options
  - Below 250grs MTOW
  - Up to 25Kg MTOW, but far away from people

Categories of operations

- EU Regulation 2019/947 and 2019/945 defines the following operations with UAS



Specific category

Specific category - Definition

- Operations falls in the specific category as soon as the Concept of Operation exceeds the limitations defined in the open category.
- Examples are flying:
  - in BVLOS
  - with a UAS with MTOM> 25 kg
  - higher than 120 m
  - for the purpose of dropping material
  - in an urban environment with a UAS with a MTOM > 4 kg or without a proper CE class mark
- Remote pilot minimum age 16, unless supervised (it may be reduced to 14)

Also autonomous operations are allowed in this category ☺

Specific category

- From the UAS/aerial robot operator point of view
  - Like Iberia/Lufthansa/Air France in the commercial aviation

- Three possibilities to fly:
  - Operational declaration:
    - Only for the two approved standard scenarios

  - Operational authorization
    - Large variety of operations, including fully autonomous (unsupervised) operations, but only low and medium risk operations
    - A risk assessment has to be performed based on SORA
    - For specific operations, operator can be used PDRA (already “cooked” SORA approved by the Aviation Authorities)

  - Light UAS Operator Certificate (LUC)
    - Optional for low and medium risk operations, mandatory for high risk operations
    - Certificate given by the National Aviation Authority (NAA) to grant an operator the possibility to start operations in the specific category without needing to apply for an operational authorization process
    - It is given for a specific fleet of UAS and for a certain type of operations
    - But it requires, among other requirements, to implement a Safety Management System

Specific category – Operational declaration

- From the UAS/aerial robot operator point of view
  - Like Iberia/Lufthansa/Air France in the commercial aviation

- Operational declaration steps:
  - Fast and easy:
    - Operation fits into one of the two standard scenarios (STS)
    - Operation is performed with a CE marked UAS for these standard scenarios (C5 or C6)
    - Operator sends the declaration to the National Aviation Authority (NAA) Not to EASA!
    - NAA confirms completeness and receipt of the declaration
    - Operator can start operating
  - However,
    - NAA can audit at any time the operator to confirm that everything that was included in the operational declaration is fulfilled
    - Can only be used with CE marked drones. Not possible to use prototypes with this option
  - Please go to your country NAA to get more information about STS-01 and STS-02 and how to submit an operational declaration

Specific category – Standard scenarios

STS-01: Characterisation

- STS defined to cover operations in **populated environment**
- Limited to:
  - Remotely piloted → **Not autonomous**
  - **VLOS**
  - Over a **controlled ground area**
  - Flight height **< 120 m** above surface (*)
  - **Class C5 UAS**
    - MTOM **< 25 Kg**
    - Characteristic dimension **< 3 m**
    - No fixed-wing UA

Specific category – Standard scenarios

STS-02: Characterisation

- STS defined to cover operations in **BVLOS in a sparsely populated environment**
- Limited to:
  - Remotely piloted → **Not autonomous**
  - **BVLOS** - UA distance to remote pilot:
    - **< 1 km** if **no visual observer** (VO)
    - **< 2 km** if **VO**
  - Over a **controlled ground area**
  - Flight height **< 120 m** above surface (*)
  - **Class C6 UAS**
    - UA MTOM **< 25 Kg**
    - UA characteristic dimension **< 3 m**

Specific category – Operational authorization

- From the UAS/aerial robot operator point of view
    - Like Iberia/Lufthansa/Air France in the commercial aviation

- Operational authorization steps:
    - Long process (around 3-6 months depending on the complexity):
        - Definition of CONOPs and application of SORA risk assessment methodology
            - If operation is low and medium risk level, then it can continue.
            - For high-risk operations, only LUC option is possible to fly
        - Operator compiles all the required documentation (Operation Manual, justification of Operational Safety Objectives and Mitigations, UAS characterization, insurance, etc.)
            - It may need information provided by the UAS manufacturer
        - Operator sends the documentation to the NAA
        - NAA revises it and there is usually some interactions to clarify aspects and include more evidences, if required
        - NAA approved the operations and send the operational authorization to the operator
        - Operator can start operating

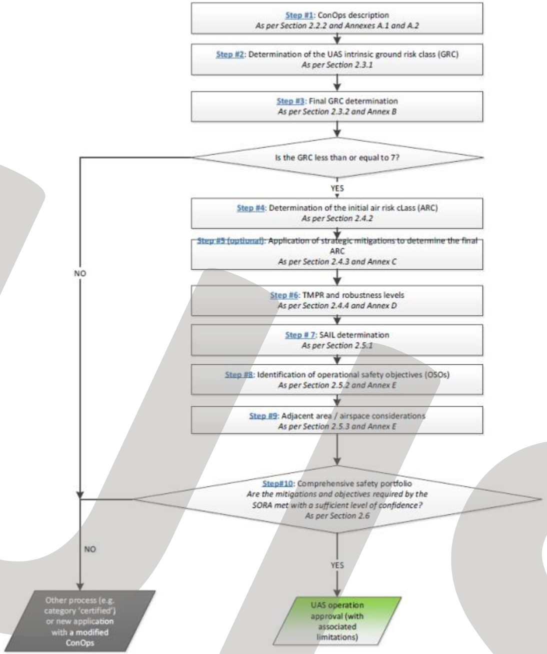
Specific category – Operational authorization

- From the UAS/aerial robot operator point of view
  - Like Iberia/Lufthansa/Air France in the commercial aviation

- SORA risk assessment methodology:
  - Qualitative risk assessment
  - Evaluate ground risk
    - How big is the aircraft?
    - Rural or urban area?
  - Evaluate air risk
    - Am I flying close to an airport?
    - Controlled or uncontrolled airspace?
    - Below 120 meters or above?
  - The combination of both risks, provides the overall risk level (SAIL from I to VI)
    - Low risk: SAIL I and II
    - Medium risk: SAIL III
    - High risk: SAIL IV, V and VI
  - Depending on the risk level, different requirements will apply (the so called OSOs)
  - Operator needs to justify to the NAA how they plan to comply with all the OSOs (and also mitigations)

- Current applicable version of SORA can be consulted at: https://www.easa.europa.eu/en/document-library/easy-access-rules/easy-access-rules-unmanned-aircraft-systems-regulations-eu

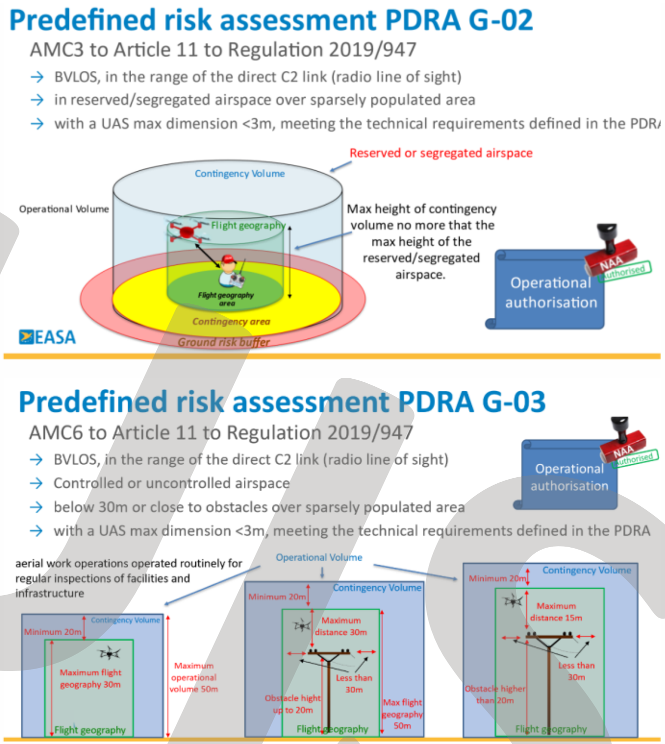
- It is a complex methodology (a lot of options), and it also requires certain experience the development of the required documentation to
  - If you do not have experience, I suggest to contact a consultancy company from your country



Specific category – Operational authorization

- From the UAS/aerial robot operator point of view
  - Like Iberia/Lufthansa/Air France in the commercial aviation

- If you operation fits a PDRA, then it is easier:
  - Operator does not need to apply SORA
  - Operator does not need to define how to justify the different requirements (OSOs) and mitigations
  - But the rest is the same as with the regular operational authorization process
  - List of PDRAs (already “cooked” SORA approved by EASA and NAAs)
    - PDRA S-01 – Agricultural works, short range cargo ops
    - PDRA S-02 - Surveillance, agricultural works, short range cargo ops
    - PDRA G-01 - Surveillance, long range cargo ops
    - PDRA G-02 - All range of ops
    - PDRA G-03 - Linear inspections, agricultural works
    - All of them are low risk operations (SAIL I or II)
    - More information about PDRAs at: https://www.easa.europa.eu/en/domains/civil-drones-rpas/specific-category-civil-drones/predefined-risk-assessment-pdra



Specific category – LUC

- From the UAS/aerial robot operator point of view
  - Like Iberia/Lufthansa/Air France in the commercial aviation

- Light UAS Operator Certificate:
  - Long process with the NAA
  - Main requirements for the operator:
    - Safety management system (SMS)
    - Remote pilot competencies along with planning, implementation, maintenance and administrative skills
    - Documentation system
    - LUC safety manual
  - Right now, the details of these requirements are not clearly defined
  - Privileges
    - To conduct operations covered by standard scenarios without submitting a declaration
    - To self-authorise operations conducted by the UAS operator and covered by a PDRA without applying for an authorisation
    - To self-authorise all operations conducted by the UAS operator without applying for an authorisation.

Specific category

- From the UAS/aerial robot manufacturer point of view
  - Like Airbus/Boeing in the commercial aviation

- Design verification of the UAS options:
  - Open category and STS: CE marked
    - For time and cost estimations, you can contact Notified Bodies (list on current Notified Bodies in previous slide)
  - Operational authorization (SORA or PDRA application):

Low-medium risk

    - SAIL I, II and III: Declaration of compliance of the drone with the technical OSOs
      - This option is very very new, so not much information available yet
      - The declaration will be submitted to the NAAs along with full package of evidences that they will audit

High risk

    - SAIL IV: Design Verification Report
      - Process in which EASA (not the NAA) confirms that UAS complies with SC-LUAS requirements
      - More information at: https://www.easa.europa.eu/en/domains/civil-drones-rpas/specific-category-civil-drones/design-verification-report
      - It can take around one year and several hundred thousands or a few millions of euros
    - SAIL V and VI: the use of a UAS with Type Certificate
      - Apply Part 21 (formally EU Regulation 748/2012) with EASA (not NAA)
      - Very complex and very costly process. Same processes used for manned aviation
        - It can take around 3 years and tens of millions of euros
  - LUC: same options as the operational authorization, depending on the SAIL level of the operations

Specific category

- From the UAS/aerial robot manufacturer point of view
    - Like Airbus/Boeing in the commercial aviation

- List of CE marked UAS

UAS with C-Class Markings

Class	Designed By	Type Category	Model	Commercial Name	Low Speed Mode	Noise Level (db)
C0	DJI	Multi-rotor	MT2SD, MT2SDCE	DJI Mini 2 SE	N/A	N/A
C0	DJI	Multi-rotor	MT3PDCE, MT3PD	DJI Mini 3	N/A	N/A
C0	DJI	Multi-rotor	MT3M3VDB	DJI Mini 3 Pro	N/A	N/A
C1	DJI	Multi-rotor	L2AA, L2PA, L2C	DJI MAVIC 3 V2.0, Cine V2.0, Classic	N/A	83
C2	AgEagle	Fixed-wing	SENSEFLY EBEE X, GEO, AG, TAC PUBLIC SAFETY	SENSEFLY eBee	No	N/A
C2	DJI	Multi-rotor	M30 RTK EU, M30T RTK EU	M30 EU, M30T EU	Yes	90
C2	DJI	Multi-rotor	M3E-EU, M3T-EU, M3M-EU	DJI MAVIC 3E EU, 3T EU, 3M EU	Yes	82
C3	Quantum-Systems	Fixed-wing	R10	Trinity F90+	N/A	N/A
C3	DJI	Multi-rotor	M350 RTK	Matrice 350 RTK	N/A	97
C6	Delair	Fixed-wing	UX11-AG-C6, IR-C6, RGB-C6, AG-LE, IR-LE, RGB-LE	Delair UX 11 Camera AG, IR, RGB; Longue Elongation Camera AG, IR, RGB	N/A	N/A

https://www.easa.europa.eu/en/domains/civil-drones/drones-regulatory-framework-background/open-category-civil-drones

Specific category

- From the UAS/aerial robot manufacturer point of view
  - Like Airbus/Boeing in the commercial aviation

- List of DVR issued by EASA (so far only subystems not complete UAS)

DVRs issued so far by EASA

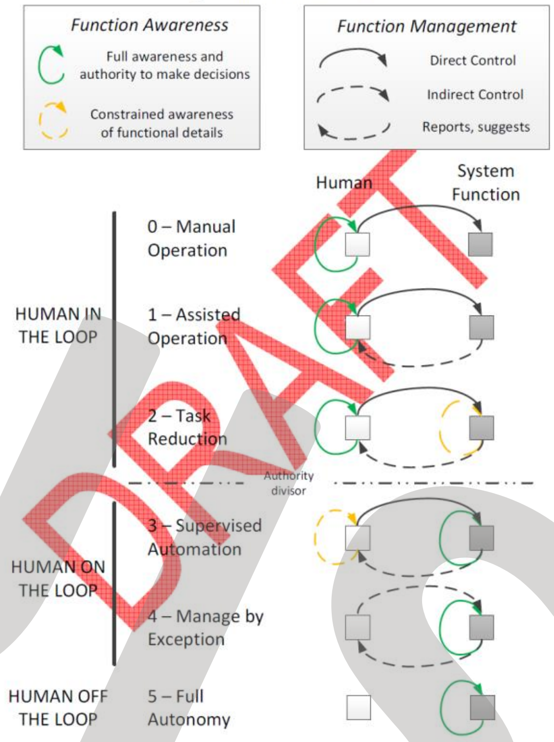
Model	Maximum SAIL	M2 Mitigation-ground risk	Enhanced Containment	Name and Website	Number	Revision	Issuance date
K250	N/A	HIGH	NO	Dronus S.p.A. https://www.dronus.it/	60079419	N/A	18.03.2022
SenseFly eBeeX	N/A	MEDIUM/HIGH	NO	SenseFly SA https://ageagle.com/	60078867	N/A	24.05.2022
VC200-2	N/A	NO	YES	Volocopter http://www.volocopter.com/	60078814	N/A	16.06.2021
Nimbus PPL-612 PLUS EVO XL	N/A	NO	YES	Techno Sky Srl. http://www.technosky.it/	60081974	N/A	30.09.2022
SKT 740	N/A	NO	YES	AZUR DRONES https://www.azurdrones.com/	60078940	N/A	05.05.2022
SX1.2	N/A	NO	YES	XSUN https://xsun.fr/	60084532	N/A	31.08.2023

https://www.easa.europa.eu/en/domains/civil-drones-rpas/specific-category-civil-drones/design-verification-report

Specific category – Autonomous operations

- The Specific category is the only category where fully autonomous operations (without a supervised pilot) is allowed
  - But only possible under the operational authorization option
- The details of how the different levels of automation has to be considered in the SORA risk assessment are not yet fully defined
- JARUS, a worldwide association of Aviation Authorities, published in March 2023 for open consultation a draft version of "Methodology for Evaluation of Automation on UAS Operations"
  - Define levels of automation for UAS operations
  - Describing functions and safety dependence
  - Impact of Automation into SORA risk analysis
- However, this work is still under development, so it will require still some time until we have a clear way how to obtain an operational authorization for a highly automatic or autonomous operation
- More information at: http://jarus-rpas.org/publications/

Figure 1 Automated methods of control



Specific category – Summary

- Include a large variety of operations
- 3 options to fly
  - Operational declaration
    - Only operations that fit into one of the two standard scenarios
    - It is required a CE marked UAS (C5 for STS01 and C6 for STS02)
  - Operational authorization
    - Only for SAIL I, II and III operations (including operation that fits into one of the published PDRAs)
    - UAS requires a declaration of compliance of the drone with the technical OSOs
  - Light UAS Operator Certificate (LUC):
    - Optional for STS and SAIL I, II and III operations(including PDRAs)
    - Mandatory for SAIL IV, V and VI operations
    - UAS requires a declaration of compliance or DVR depending on SAIL level
- Please remember that this applies to aerial works and experimental flights
- However, experimental flights can be performed in dedicated test flight centers
  - This flight test centers usually has a set of mitigations (like segregated airspace or unpopulated area around) that usually allows to fly long distances or large aircrafts under SAIL I, II or III at most

Categories of operations

- EU Regulation 2019/947 and 2019/945 defines the following operations with UAS

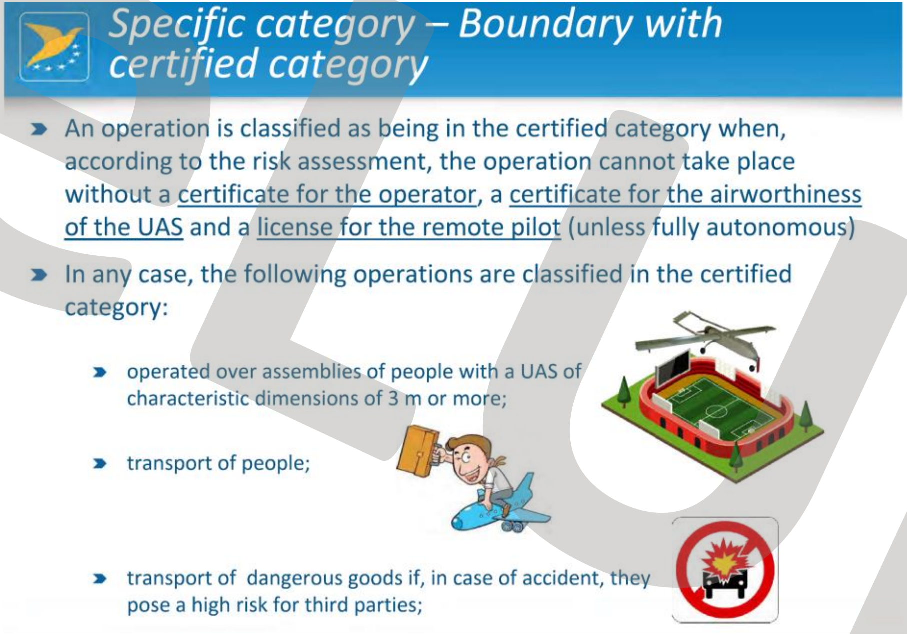
OPEN:
Low risk
Competent Authority notified by Member States; no-pre approval envisaged
Limitations (25 kg; Visual line of sight (VLOS), Maximum Altitude, no drone zones, limited drone zones)
Rules: no flight over crowds, pilot competence
Use of technology
Sub-categories including harmless

SPECIFIC
Increased risk
Approval based on Specific Operation Risk assessment (SORA)
Standard scenarios
Approved by NAA possibly supported by accredited QE unless approved operator with privilege
Manual of Operations mandatory to obtain approval
A risk assessment approach allow to take into account new technologies and operations

CERTIFIED
Regulatory regime similar to manned aviation
Certified operations to be defined by implementing rules
Pending criteria definition, EASA accepts application in its present remit
Some systems (Datalink, Detect and Avoid, ...) may receive an independent approval

Certified category

- Boundary between the Specific and the Certified categories



Certified category

- This category requires a pilot
- Same regulation as manned aviation:
  - Adapted to the fact the fact that part of the system is not on the aircraft (the informally known control station) and crew is not on-board
  - Certification of the operator, certification of airworthiness for the UAS (design, manufacturer and maintenance certifications), and official license for the remote pilot (not required in the Open and Specific categories)
- Recently, EASA published an Opinion (previous formal process to publish a EU regulation related to aviation) related with the Certified category and the eVTOL aircrafts (also manned) for innovative aerial mobility services
  - Opinion 03/2023: https://www.easa.europa.eu/en/document-library/opinions/opinion-no-032023
- We are far away into the application of aerial robotics technologies and systems for the certified category
- Also, EASA has published a second version of the roadmap about the application of IA (data driven approaches) for aviation application
  - More information at: https://www.easa.europa.eu/en/newsroom-and-events/news/easa-artificial-intelligence-roadmap-20-published

UAS integration into the airspace

- So far, we have “just” commented the requirements for the UAS operator and manufacturer without considering the integration of the UAS into the airspace
- This is specially relevant for BVLOS operations -> the pilot is not able to directly operate the aerial robot with his/her eyes
- Right now there are four main options for BVLOS operations (only for Specific and Certified categories)
  - Operate into a segregated airspace -> not really an integration into the airspace
    - For example this is what usually happens in test flight centers
  - In non-segregated:
    - Operate below 150m above ground level (AGL) where there is very limited manned traffic. Two main options:
      - In non-controlled airspace, making use of a qualified Detect and Avoid system with coordination operational procedures
      - Operate in U-Space airspace (within controlled or un-controlled airspace) using the services of a U-Space Service Provider (USSP)
    - Operate above 150m AGL
      - Then, it will be required to operate following visual or instrumental flight rules (VFR or IFR) and with the same requirements as manned aircrafts (ATM/ATC regulation) but the pilot is not on-board the aircraft.
      - Very difficult and costly. Aeronautical industry is working in achieving this for certain types of airspaces and only for the Certified category

UAS integration into the airspace

- Operations in non-segregated airspace below 150m AGL
  - In non-controlled airspace, making use of a qualified Detect and Avoid system with coordination operational procedures
    - Not yet available on the market a qualified Detect and Avoid system
      - It can be on-board the aircraft or using ground infrastructure
    - Right now, EUROCAE (European aeronautical standardization body) is working on defining the requirements for a qualified Detect and Avoid system for operations below 120m AGL

  - Operate in U-Space airspace (within controlled or un-controlled airspace) using the services of a U-Space Service Provider (USSP)
    - EU Regulations 2021/664, 2021/665, 2021/666
    - More information at: https://www.easa.europa.eu/en/regulations/U-space
    - U-space is only for Europe. A similar concept is developed in other parts of the world under UTM acronym (Unmanned Traffic Management)

UAS integration into the airspace

- Why U-Space?

Now	2035
Whole Europe	One city
30K manned flights	20K drone flights
24h	1h

- Then, we need a digital system automating air navigation service provision

U-Space

- U-Space is a new type of airspace
  - It can be within a controlled or un-controlled airspace
- U-Space airspaces are designated by the NAAs within their national geography, and before that, they need to perform an airspace risk assessment
  - Not a SORA, this is a different risk assessment which is more complex.
- NAAs have to define a CIS (Common Information Service) which is a unique and trusted data exchange point between ATM and U-Space ecosystems)
- Once a U-space airspace is formally defined and CIS is certified and operational, certified U-Space Service Providers (USSPs) can start offering their services in this U-space airspace
  - Four mandatory services:
    - Network identification
    - Geo-awareness
    - UAS flight authorisation
    - Traffic information
  - Two optional services:
    - Weather information
    - Conformance monitoring

U-Space

- What are the advantages to operate in an U-space airspace?
  - For the SORA analysis and BVLOS operations, the air risk will usually be ARC-b (low air risk)
  - It is a digital and automated system, so UAS flights will be authorized fast and with easy-to-use interfaces
  - In the future, it will facilitate the operation of UAS in airspaces with a lot of UAS operations (high density)
- Does the operation in U-Space airspace impose further requirements for the UAS operator or manufacturer?
  - Yes, although only right now high-level requirements are defined in U-Space AMC/GM (Acceptable Means of Compliance / Guidance Material)
  - More information at: https://www.easa.europa.eu/en/document-library/acceptable-means-of-compliance-and-guidance-materials/amc-and-gm-implementing
- Which is the current status of the implementation of U-Space?
  - The European regulation come into force January 2023 (only a few months ago)
  - There is not yet a official U-Space airspace defined in Europe
  - Then, it is not possible yet to use U-space services
  - IT is expected that first U-space airspaces and USSP services will be launched during next year

Thanks for your attention!

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