Drone Operative Configurations and Applications

Smart Infrastructures & Construction Academy

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Outline

- Drone Operative Configurations
- Flight Mission Management
- Drone Applications
- References

Overview

Drawbacks of Traditional aviation with manned aircraft

1. High maximum takeoff mass
2. Safety against injuries (mechanical, electrical, contamination)
3. Physiological limitations (acceleration, rotation rate, air pressure, temperature)
4. Unpredictable behavior
5. Unwilling to execute remote commands
6. Potential malicious use of aircraft.

Drone Operative Configurations

Nomenclature

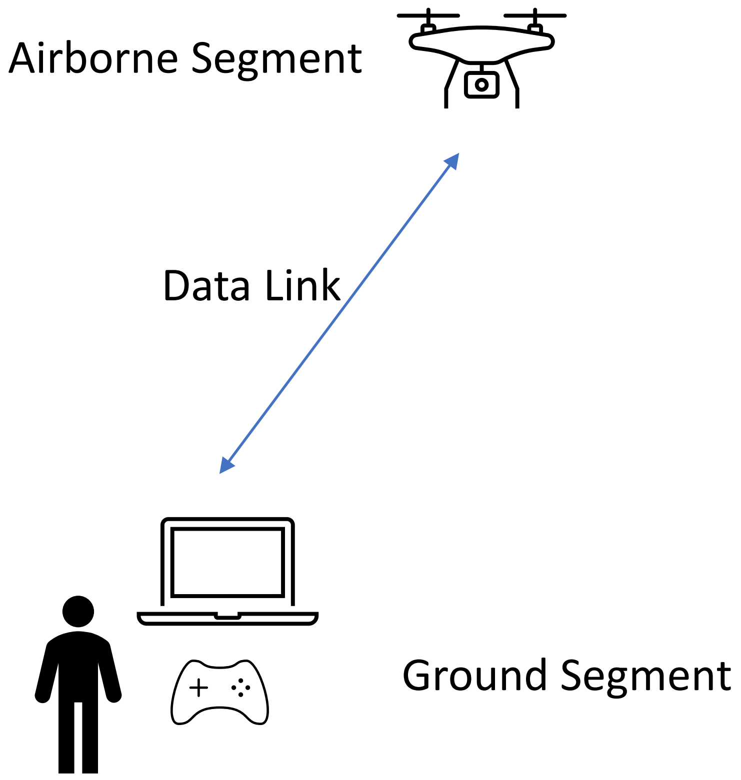
UAS: Unmanned Aerial System

UAV: Unmanned Aerial Vehicle → Airborne Segment

RPAS: Remotely Piloted Aircraft System
(SAPR: Sistema Aeromobile a Pilotaggio Remoto)

Drone: usually small RPAS

GS: Ground Station



Drone Operative Configurations

Components

- Airframe
- Propulsion System
- Fuel/Battery system
- Takeoff and Landing system
- Servo Actuators
- Avionics system with Flight Management Computer
- Communications: (C2-Command and Control [TLC/TLM], Payload, and ATC)
- Payload: electro-optical sensors (cameras, lidar, multi-/hyper-spectral sensors, …), microwave sensors (radar, sounder), chemical sensors (emissions, particulate, …), communications (relay, ….)

Drone Operative Configurations

Classification

Traditional

- >0kg and <=25kg: Small UAS subject to National Authorities Approval
- >25kg and <=150kg: Light UAS subject to National Authorities Approval
- >150kg subject to EASA approval

Classification replaced by January, 1st 2021.

Current

UASs are classified in classes (C0-C6)

Drone Operative Configurations

Classification

Commercial drones are divided in classes (with CE marking) depending on their specifications and performance (EU, 2019a,b)

General characteristics of drone classes

Class	MTOM	Max speed	Max height	Max noise	eID	Geo-aware	Lights	Serial no.
C0	250g	19m/s	120m	-	N	N	N	N
C1	900g	19m/s	120m	60db(A)	Y	Y	Y	Y
C2	4kg	-	120m	60db(A)	Y	Y	Y	Y
C3	25kg	-	120m	-	Y	Y	Y	Y
C4	25kg	-	-	-	-	-	-	-

Synthesis of drone Classes specifications according to EU Reg 2019/945 (CORUS, 2019)

- Classes C5 and C6 of later definition (amending EU Reg, 945/2019, May 2020) by extension of C3 class limitations in order to comply with two new Standard Scenarios (STS-01, STS-02)
  [in brief: C5/C6: no max height + equipment, C5: 5m/s-reduced-speed mode, C6: 50 m/s max speed]

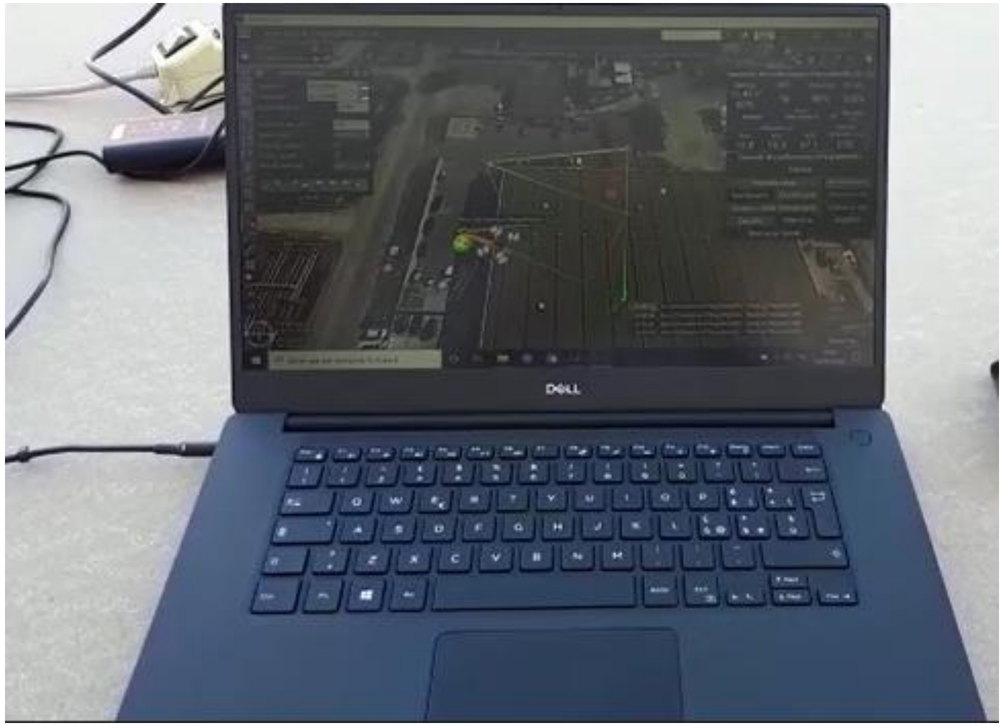
Drone Operative Configurations

Flight Modes

1. Manual Flight

2. Automatic Flight

3. Autonomous Flight



Collision Avoidance Systems
(in support of manual or automatic flight) are not "Autonomous Flight"

Drone Operative Configurations

Types of operation in Remotely Piloted (Manual) Flight

- Any operation under the **active control of a remote human pilot**
  - the remote pilot is in control of the aircraft
  - He is responsible for their own aircraft “Remaining Well Clear” (RwC) of other aircraft (if the airspace class requires that)
- **Visual Line of Sight** (VLOS)
  the remote pilot shall maintain visual contact the aircraft at all times during flight
- **Beyond VLOS** (BVLOS)
  the pilot is not in visual contact with the aircraft
- “**First Person View**” (FPV) operation is a variant of either VLOS or BVLOS
  - the remote pilot views images sent from a video camera in the aircraft
  - FPV is VLOS if and only if an assistant (positioned next to the remote pilot) maintains visual contact with the drone, as the remote pilot usually wears goggles during FPV
  - FPV is considered a variant of BVLOS in the absence of such an assistant

Drone Operative Configurations

Autonomous operation

- Onboard-Human-Pilot aviation is expected to manage dangerous situations such as potential collisions with other airspace users, clouds and severe weather conditions, obstacles and ground operations at aerodromes through the ability of a pilot to "see and avoid" these hazards.

- The absence of a pilot on-board also brings the challenge, therefore, of replicating this ability on the UAS, a concept known as “Detect And Avoid (DAA)”
[DAA shall be intended as the capability to see, sense or detect conflicting traffic or other hazards , and take appropriate action (ICAO definition)]

Flight Mission Management

Operative Environment

↓

Flight Planning — Setting flight parameters to properly cover the desired area

↓

Mission Execution — Endurance limits, battery management

↓

Data Processing — Post processing

↓

Output Analysis — Results and validation

Drone Performance

GN&C
Guidance → nominal route
Navigation → current state estimation
Control → actions to follow the nominal path from the current state

Accuracy of GN&C systems affects the accuracy of the desired mission parameters. Trade-off between system performance and costs

Drone Performance

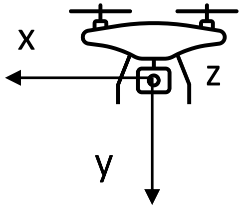
Global Navigation Satellite System (GNSS) for positioning → if GNSS signal is weak, barometer can be used for altitude keeping.

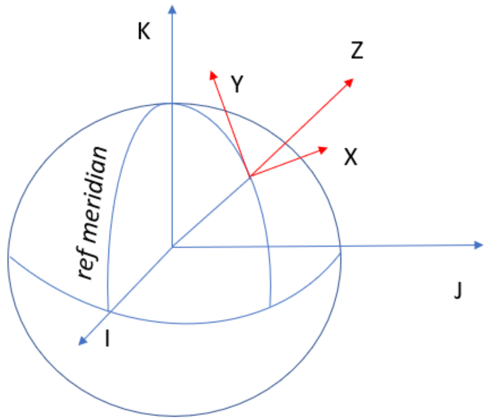
Real Time Kinematics RTK → ground station to improve positioning (centimetric level)

Inertial Navigation
Position and attitude estimation and update based on measurements of accelerometers and gyroscopes

Attitude estimation → from Camera Reference Frame (CRF) to the Local Reference Frame (LRF)

Visual positioning → camera specifications, image processing technique accuracy





- CRF
- ENU-East North Up LRF

Obstacle Avoidance Systems

Involved Obstacle Detection techniques:

- VLOS remote pilot (main responsibility of flight mission)
- Visual sensors (IR, RGB systems)
- Lidars, RADARs (large vehicles)

Critical to reduce the operational risk level (i. e. Specific Operation Risk Assessment)

Automatic obstacle detection for protection against human error (collision avoidance)

Communications and Data Bus

Command and Control (C^2) link (Telecommand/Telemetry)

- Uplink: remote pilot commands, payload operation commands
- Downlink: telemetry data, payload data

Issues

- Low latency, robustness to disturbances, security (no malicious spoofing)

Dedicated link

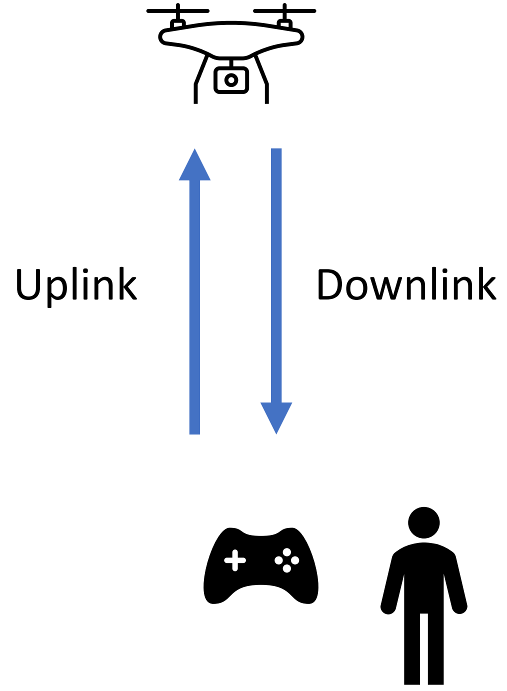
- Frequency & TxPower compliance with National Regulation
- Limited range from GS

Communication Network Layer

- **5G**
- SatComm

On-board functionalities

- Procedures for data-link lost (holding, Return-to-Home,…)
- Return to Home capability



Communications and Data Bus

Further Drone Communications

(in view of "dense" drone traffic and implementation of the UAS Traffic Management System)

- Drone to/from Traffic Management Infrastructure
- Drone to/from Surrounding Drones
  (D2D – Cooperative collision avoidance, contingency management)

Dedicated link

- Frequency & TxPower compliance with National Regulation
- Expensive for wide coverage wrt Traffic Management Infrastructure

Communication Network Layer

- **5G**
- SatComm

Issues

- Low latency, robustness to disturbances, security (no malicious spoofing), identification/status/ localization shall be provided

Weather Limitations

- Vehicles limits → in drone manual (e.g. Beaufort scale)
- Payload limits → measurement accuracy

Equipment: weather stations (fixed or mobile)

Observation and forecast:

- METeorological Aerodrome Report (METAR)
- Terminal Aerodrome Forecast (TAF)
- Local weather forecast

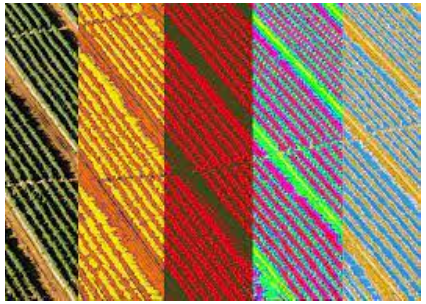
- In future: dedicated service in support of Unmanned traffic

Payloads: Electro-Optical Sensors

- VIS cameras (b/w, RGB color) [400-700 nm]
- IR cameras
  - Near IR [700-1400 nm]
  - Short-wavelength IR [1.4 nm-3nm],
    unique ability to 'see' through atmospheric haze, whether moisture, dust or smoke; gas (hydrocarbon) source detection;
  - Thermal IR [3-8 μm]

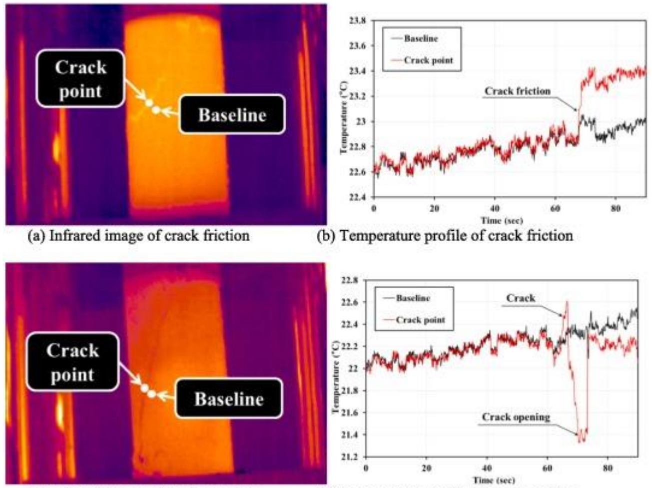
- Multi-spectral cameras
  acquiring simultaneously images in different bands (e.g., RGB camera)
- Hyper-spectral cameras
  like multispectral but with a very large number of bands (typically quite narrow)

- Integrated suites of sensors



Electro-Optical Sensors Applications

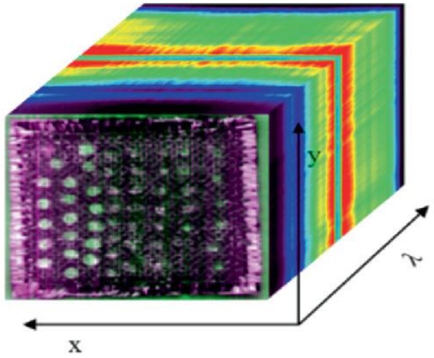
- Thermal sensors:
  - Thermal imaging, temperature estimation
  - Leakage analysis
  - Crack analysis



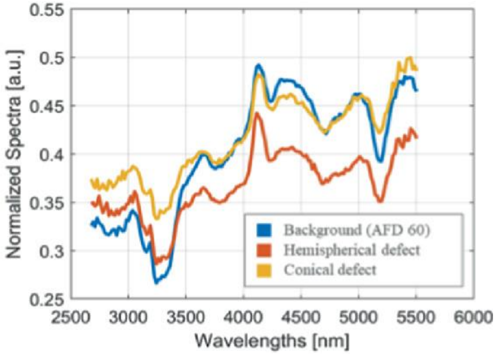
(a) Infrared image of crack friction (b) Temperature profile of crack friction

(c) Infrared image of crack opening (d) Temperature profile of crack opening

- Multi-/Hyperspectral sensors
  - Product quality
  - Damage detection in composite



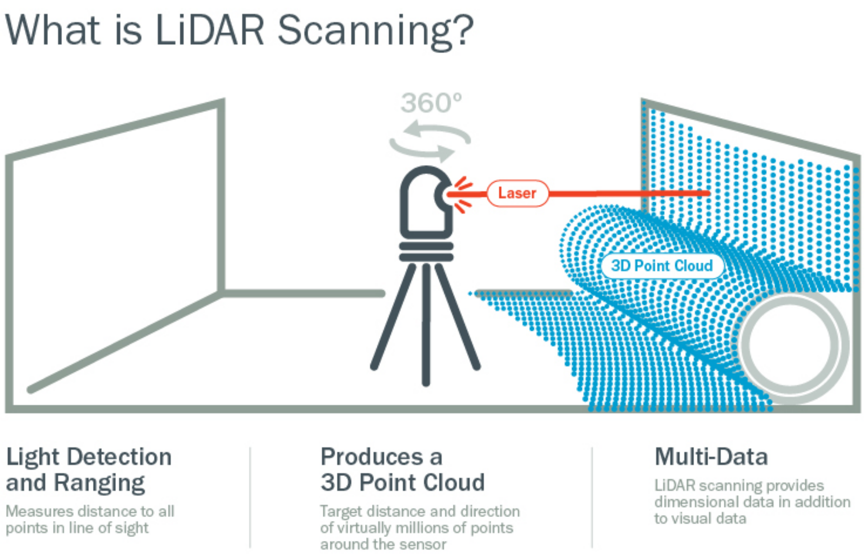
(a) Hypercube of AFD 60 specimen

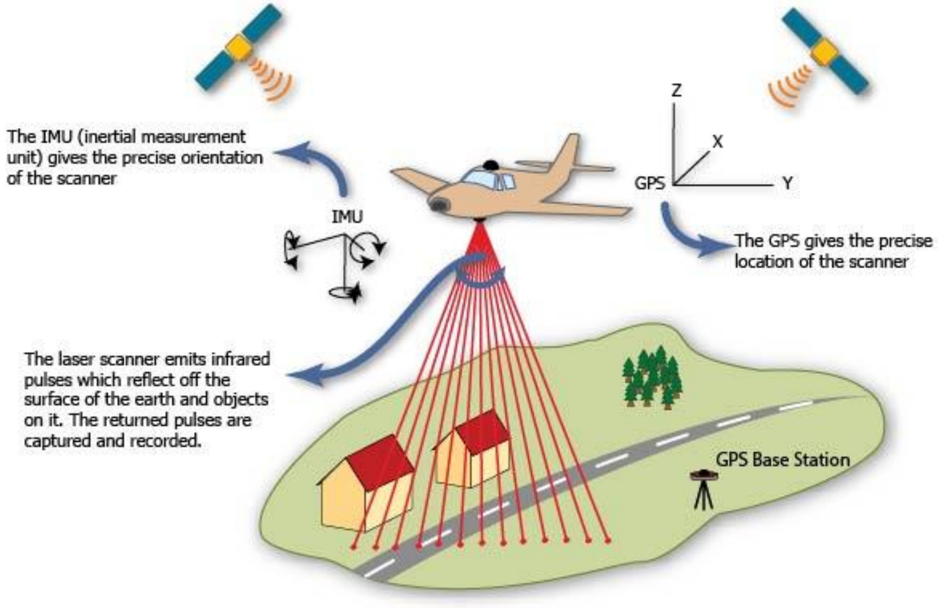


(b) Reference spectra

Payloads: Electro-Optical Sensors

- LIDAR "light detection and ranging" or "laser imaging, detection, and ranging" is a method for determining ranges by targeting an object or a surface with a laser and measuring the time for the reflected light to return to the receiver.





- Integrated VIS & Lidar sensors

Payloads: MicroWave Sensors

RADAR: radio detection and ranging
a device or system consisting of a synchronized radio transmitter and receiver that emits radio waves and processes their reflections for display and is used especially for detecting and locating objects or surface features

- Surveillance/countermeasure, surveys, collision avoidance

- Active device, high power consumption
- Radar Sounder/Ground-penetrating radar (GPR) (low frequency, <2.5 GHz), sub-surface detection

Payloads: Chemical Sensors

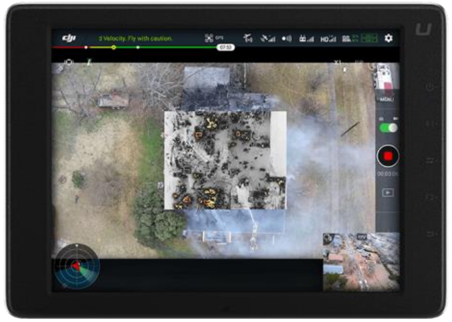
Chemical Sensors (sniffers)

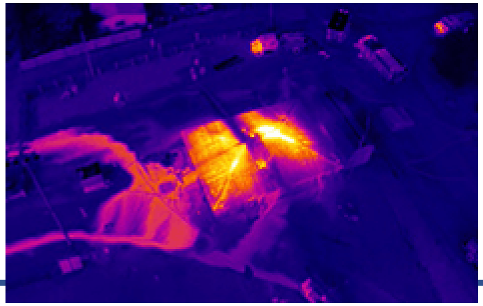
- local Air Pollutant Mapping System
- From moving vehicle:

  local Air Pollutant Mapping System;

evaluate the concentrations of pollutants and the spatial extent of contaminants, e.g. Inhalable Particulate Matter (PM2.5&10), O3, NO_2, CO, SO_2, Volatile Organic Compounds (VOCs), H_2S, CH_4, CO_2, NH_3, NO, radiation

Drone Applications: Present



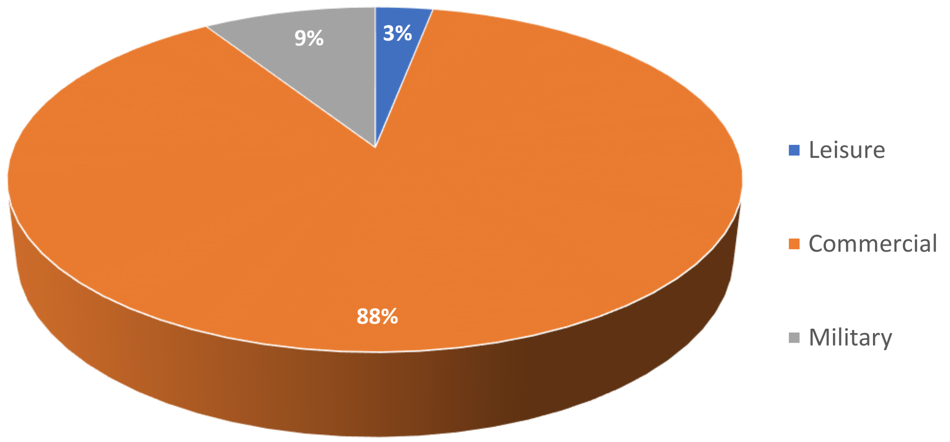


Drone Applications: Present

According to the European Outlook Study (SJU, 2016):

- **Agriculture sector**: over 125 000 drones by 2035
- **Energy sector**: close to 10 000 drones by 2035 preventative maintenance inspections
- **Delivery and transport purposes**: nearly 70 000 drones delivery + 10 000 mobility urgent service capabilities
- **Public safety and security**: 50 000 drones by 2050 for authorities such as police and fire forces

15 billion Euros in 2050



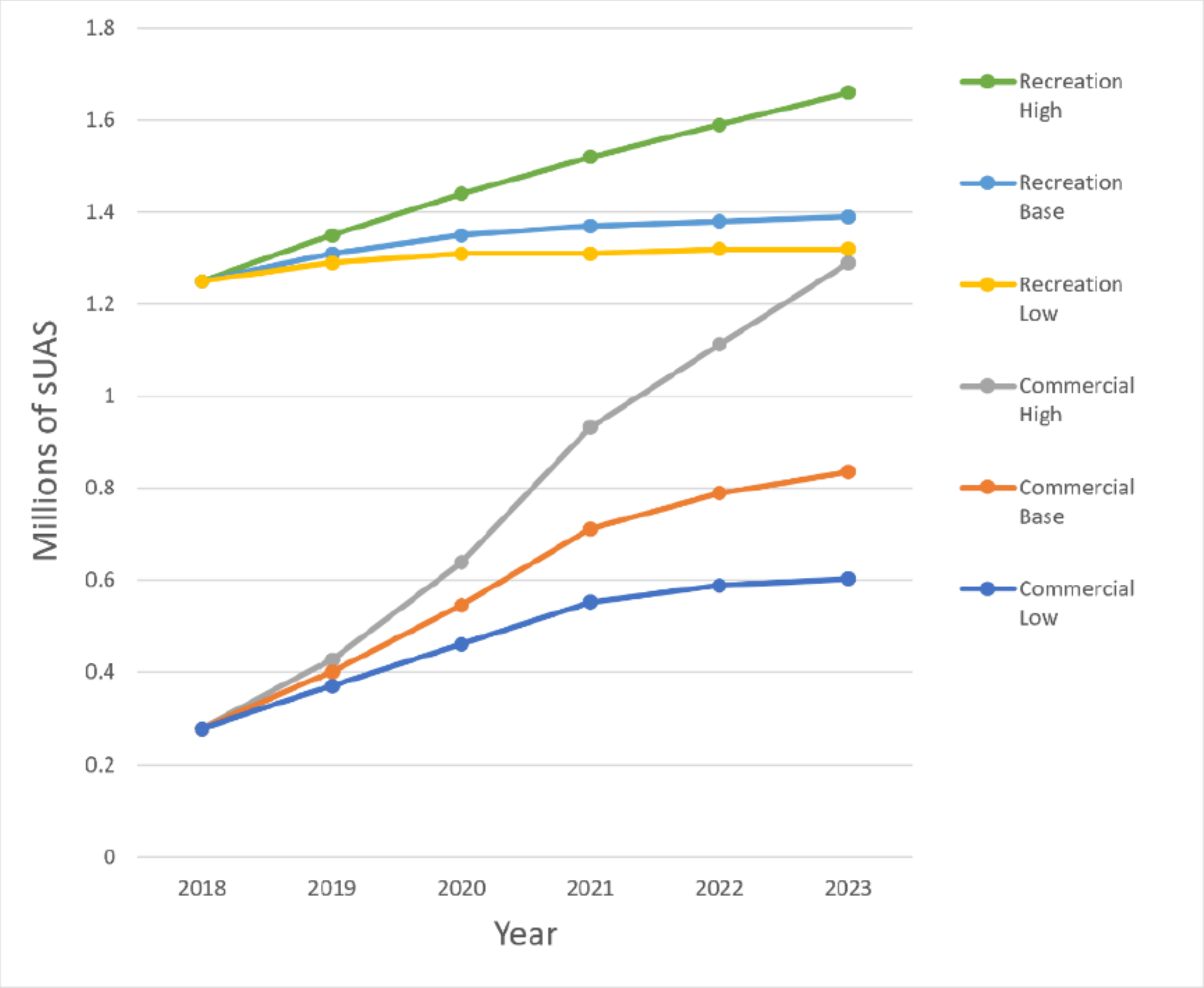
Drone Applications: Present

- **Infrastructure Inspections,** oil refinery, buildings, natural sites, electric power lines, railways, highways, pipelines
- **Smart Agriculture,** topographic survey, crop monitoring
- **Communication Network**, rely messages with low latency
- **Countermeasure,** protection of sensible targets
- **Industry 4.0,** maintenance, inspections
- **Surveillance and S&R,** construction sites, sensitive areas, fire-fighter and police forces operations

Drone Applications: Future

It is estimated that the **European drone market** will represent EUR 10 billion annually by 2035 and **over EUR 15 billion annually by 2050** and the drone sector will create **more than 135,000 jobs** (SJU, 2016):

- **7 million consumer leisure drones** are expected to be operating across Europe and a fleet of **400000** is expected to be used for **commercial and government missions** in **2050**.
- **Commercial and professional** users are expected to demand drones:
  - in both **rural and urban settings,** and
  - will be reliant on **beyond visual line of sight capabilities** to be permitted.



(FAA, 2020)

Drone Applications: Future

Most influential future missions, in terms of the potential number of drones and economic impact (SJU, 2016; SJU, 2018):

Agriculture sector: over **100 000 drones** are forecasted to enable precision agriculture to increase levels of productivity

Energy/infrastructure sector: close to **10 000 drones** limit risk of personnel and infrastructure by performing preventative maintenance inspections

Delivery purposes: potential for a fleet of nearly **100 000 drones** to provide society with some kind of urgent service capabilities, such as transporting emergency medical supplies, and "premium" deliveries

Public safety and security: forecasted fleet of approximately **50 000 drones** would provide authorities like **police** and **fire forces** the means to more efficiently and effectively locate endangered citizens and assess hazards as they carry out civil protection and humanitarian missions.

→ Also <u>environment protection</u> is in this sector

Urban Air Mobility: Urban Air Mobility is expected to become **a reality in Europe within 3-5 years** (EASA, 2021)

Applications: Infrastructure Inspection

3D reconstruction (point cloud and mesh) with specific path planning

Point cloud

Textured mesh

Applications: Smart Agriculture

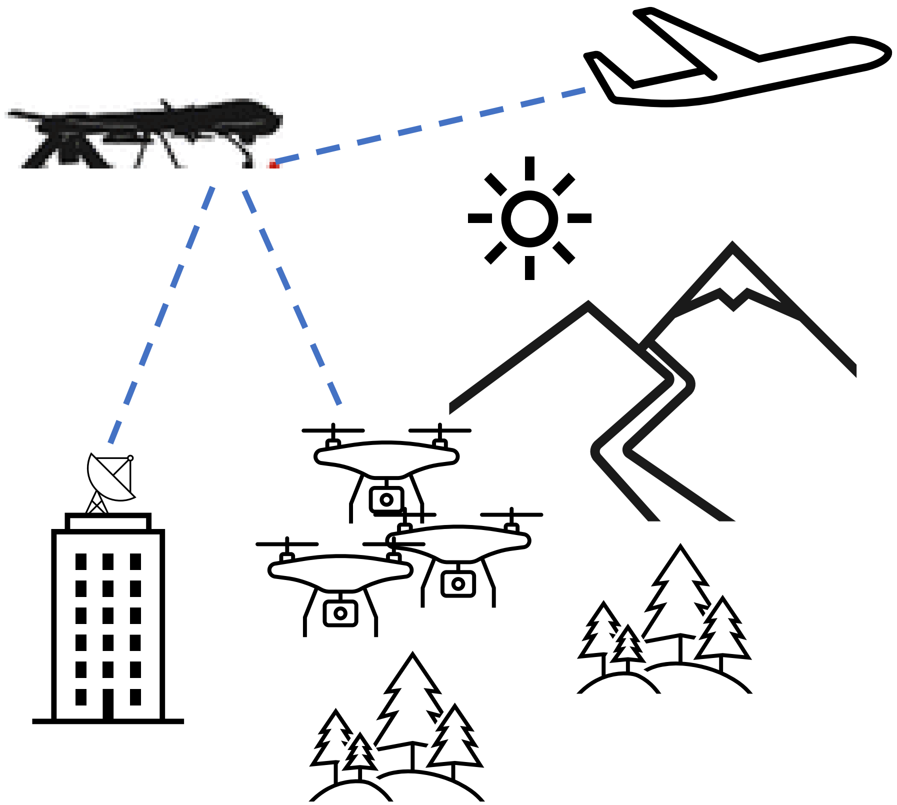
- Vegetation monitoring
- Crop healthy status
- Weeds monitoring
- Spraying

Thermal cameras, Multi/Hyper-spectral cameras, RGB cameras

Vegetation with comparison between the NIR band and RGB bands

Applications: Communication Network

- 5G communications can be exploited to provide low latency data
- Some providers, such as Google and Facebook planned to use high-altitude drones as relay for Internet signal



Applications: Countermeasures

Dual task:

- Countermeasures against drones
- Drones as countermeasure

Radars can be used as onboard systems for obstacle detection and altimetry analysis

Applications: Industry 4.0

- Airfield, towers, antennas, buildings inspections
- Maintenance operations

- Remote sensing requires classification of observed large regions
- Dedicated sensor configurations are adopted depending on the type of application
- Dedicated software is needed for processing

Applications: Delivery and Transportation

Small Drones

- Delivery of goods (e-commerce)
- Delivering emergency medical supplies
- Deliveries in remote areas
- Cost-efficient deliveries

Large Drones

In the longer term, unmanned larger commercial vehicles are gradually expected with initial versions of optionally piloted systems estimated for sometime after 2030 – first impacting cargo transport and then moving slowly towards transport of passengers (Eurocontrol, 2018)

Applications: Urban Air Mobility

June 2020 FAA → "UAM Concept of Operations (ConOps) version 1.0 with both internal and external stakeholders" to support the development of unmanned operations around urban areas Specifically, UAM and AAM concepts are described:

- Urban Air Mobility (UAM) → Passengers transport and/or cargo at low altitudes in urban or suburban areas

- Advanced Air Mobility (AAM) → UAM operations not limited to urban environments, such as long-range travels, public services, private vehicles

Drone Applications: Future

Urban Air Mobility - Examples

- Airbus
- Amazon
- Uber
- Volocopter
- Embraer
- EHang

Drone Applications: Future

Urban Air Mobility – A Selection of Recent News [https://www.urbanairmobilitynews.com/]

Birth of an industry: Urban air mobility flights to start in 2023

November 19, 2022 AAM/UAM route and programme news

Welcome to the first edition of our regular monthly AAM/UAM city and route development analysis report, based on data compiled within our Global AAM/UAM Market

Read more

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Very close observers of this industry will argue that the industry has already taken off. In July this year EHang performed sightseeing flights with passengers in Yantai, a coastal city in East China, as part of the EHang 216 'World Flight Tour'.

…….

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Sight-seeing is the one of the key drivers of initial services. In 2021 September, EHang reached a cooperation agreement with China Eastern General Aviation, a helicopter service provider and airspace management company, for tourism flights in Malunshan Base, Linhai, Shenzhen. eHang eVTOL tourist services are also scheduled for the Guangdong-Hong Kong-Macao Greater Bay Area. Other early tourist flights planned include the Volocopter scenic circular path within the Marina Bay area (9km) of Singapore and a 6km hop around Jeju Island in Korea.

Some of the flights could take place in 2024 – depending on the speed of ***certification***.

……

Drone Applications: Future

Urban Air Mobility – A Selection of Recent News

[https://www.internationalairportreview.com/topic/urban-air-mobility-uam/]

NEWS

FAA releases new vertiport design guidelines to ensure safety

27 September 2022 | By International Airport Review

The Federal Aviation Administration has released new design guidelines for vertiports, to support the safe integration of Advanced Air Mobility aircraft.

NEWS

FCO deploys Italy's first vertiport

13 October 2022 | By International Airport Review

Fiumicino's Leonardo da Vinci International Airport has welcomed the first crewed eVTOL test flights in Italian airspace, a key milestone towards the envisioned rollout of advanced air mobility.

NEWS

Abu Dhabi Airports signs deal to accelerate the future of AAM

21 November 2022 | By International Airport Review

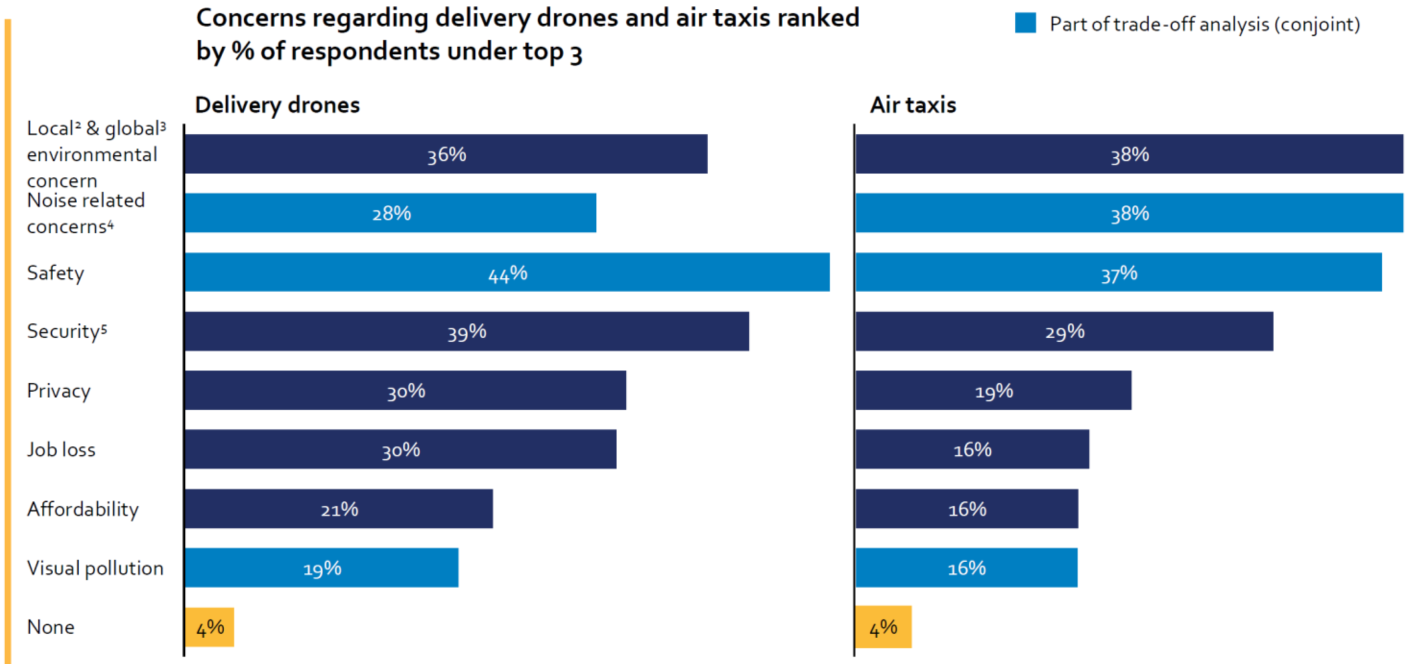
Abu Dhabi Airports has signed an agreement to work collaboratively with Groupe ADP to explore the future of Advanced Air Mobility in Abu Dhabi.

Applications: Surveillance and S&R

- Search and rescue (lost people in remote areas, such as sea, mountains, and wooded areas)
- Law Enforcement (territorial control)
- Disaster Response (flooding, earthquakes, hurricanes, chemical and nuclear contaminated areas)
- Surveillance (border patrolling, smuggling, drug traffic, and military operations)

Social Acceptance

Surveys and Statistics



1. Incident due to technical or human failure
2. Local environmental impact includes air pollution, negative impact on bird life and insects, decreasing biodiversity
3. Global environmental impact covers climate change
4. Covers noise pollution for delivery drones, and noise related to flying aircraft and noise related to vertiports for air taxis
5. Incident due to deliberate harmful action, e.g. by criminal organization or terrorists

Full Report - Study on the societal acceptance of Urban Air Mobility in Europe | EASA. https://www.easa.europa.eu/en/full-report-study-societal-acceptance-urban-air-mobility-europe

Social Acceptance

Surveys and Statistics

- Noise. Propeller design and urban areas regulation.
- Privacy. Registration if drone is equipped with a camera and not a toy. General Data Protection Regulation GDPR UE 2016/679 for data collection. Strategic position from high point of view (FOV impact).
- Safety. Aeronautical standards with high integrity and robustness levels.

Full Report - Study on the societal acceptance of Urban Air Mobility in Europe | EASA.
https://www.easa.europa.eu/en/full-report-study-societal-acceptance-urban-air-mobility-europe

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