UAS Payloads – Session 2

Robótica Aérea

Xin Chen/Manuel Barriopedro

LiDAR

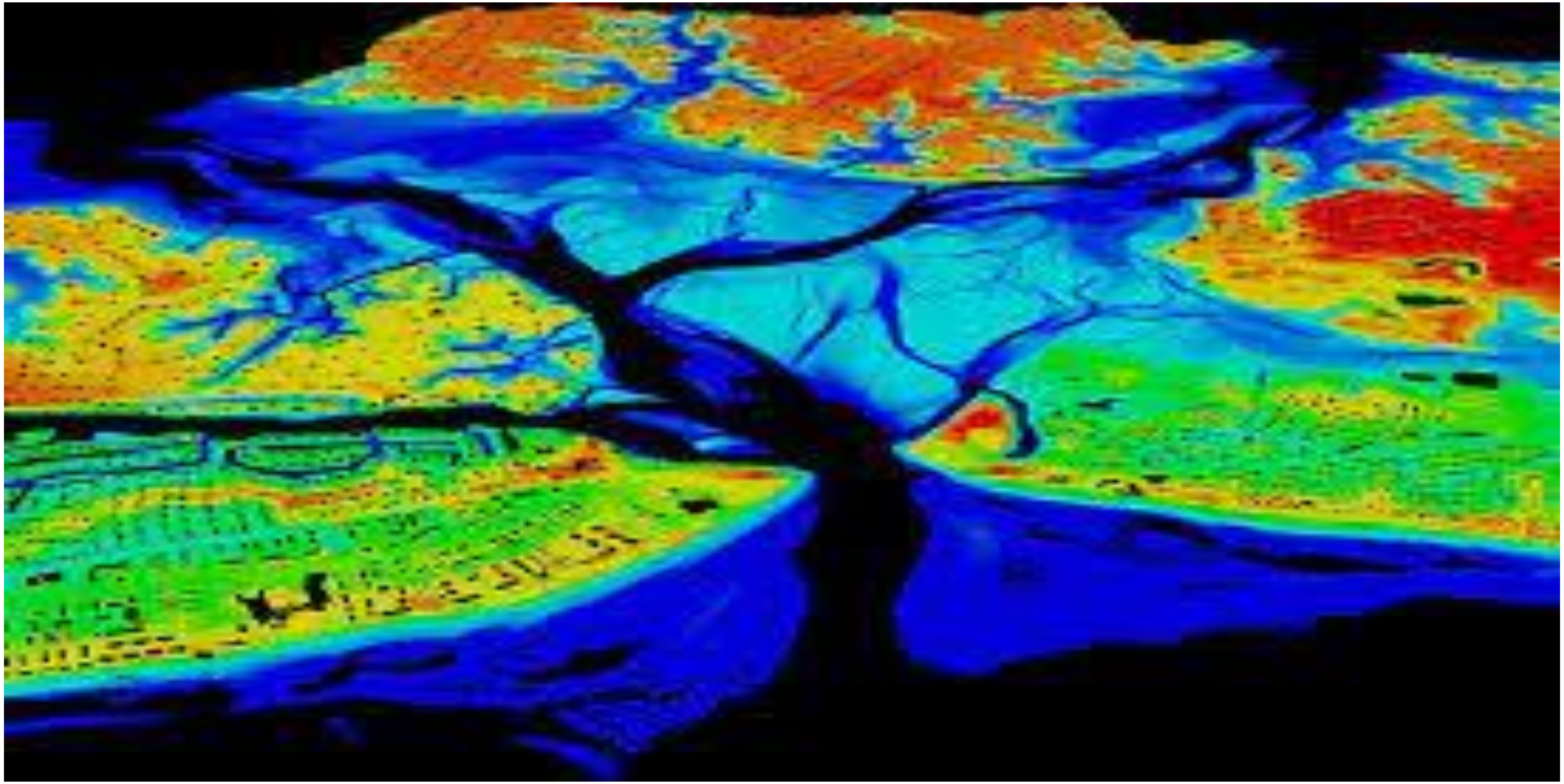


Figure: LiDAR Image [Source: National Ocean Service]

LiDAR

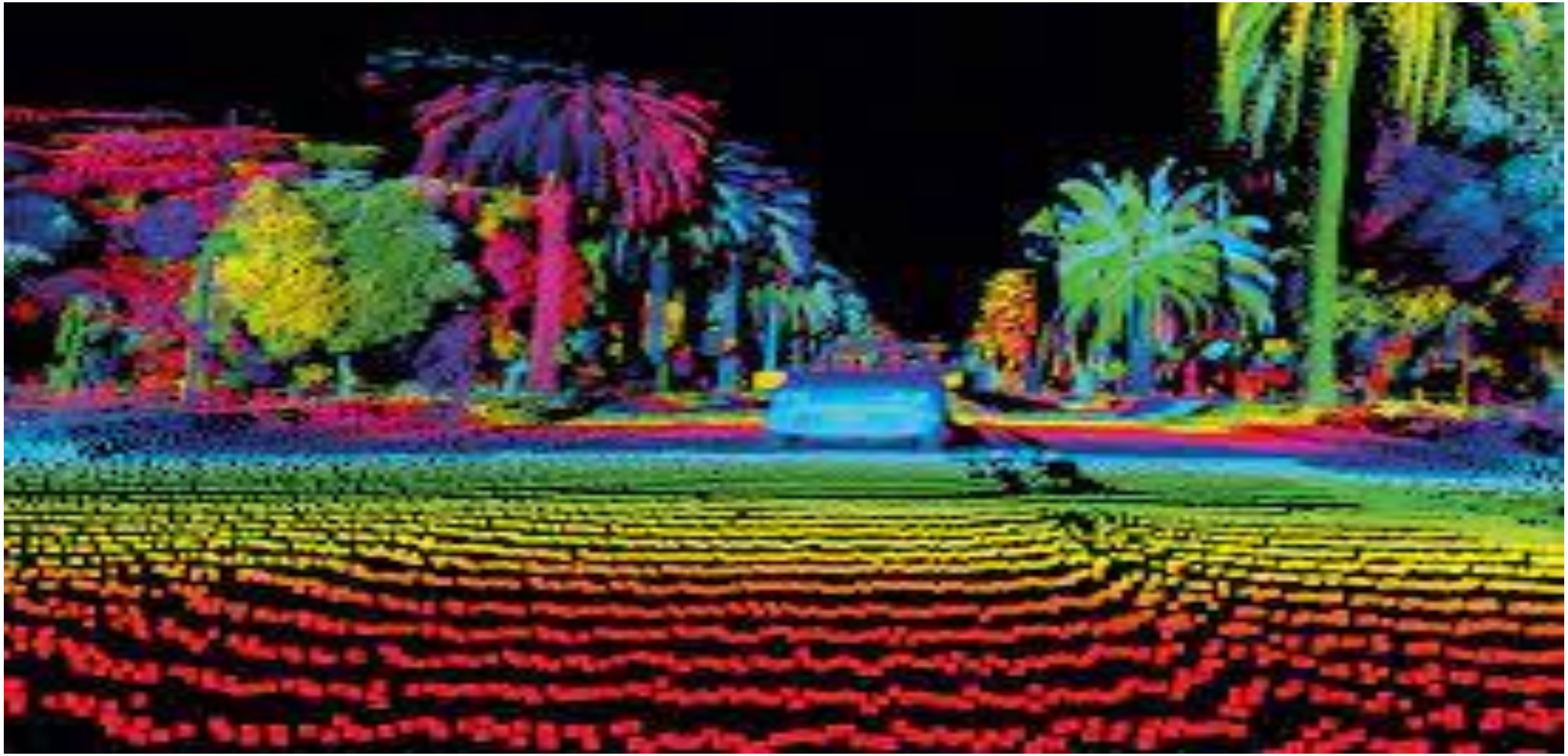


Figure: Volvo Self´s Driving Car [Source: Geospatial World]

LiDAR

- Lidar: **LIght Detecting and Ranging** or **Laser Imaging Detecting and Ranging**

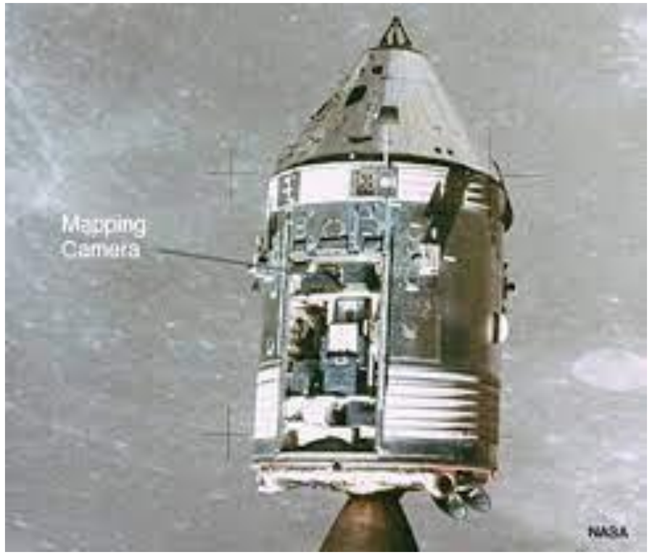
- It can be considered analogous to radar imagery:
  a. Both transmit energy in a **narrow range of frequencies**, then receive the backscattered energy to form an image.
  b. Both are **active sensors** that provide their own sources of energy, being independent of solar illumination.
  c. They can **compare the characteristics of the transmitted and returned energy** (the timing of pulses, the wavelengths, and the phases) to
     a. Determine ranges by targeting an object with a laser and measuring the time for the reflected light to return to the receiver
     b. Extract information describing the **structure** of terrain and vegetation features not conveyed by conventional optical sensors (3D representations)

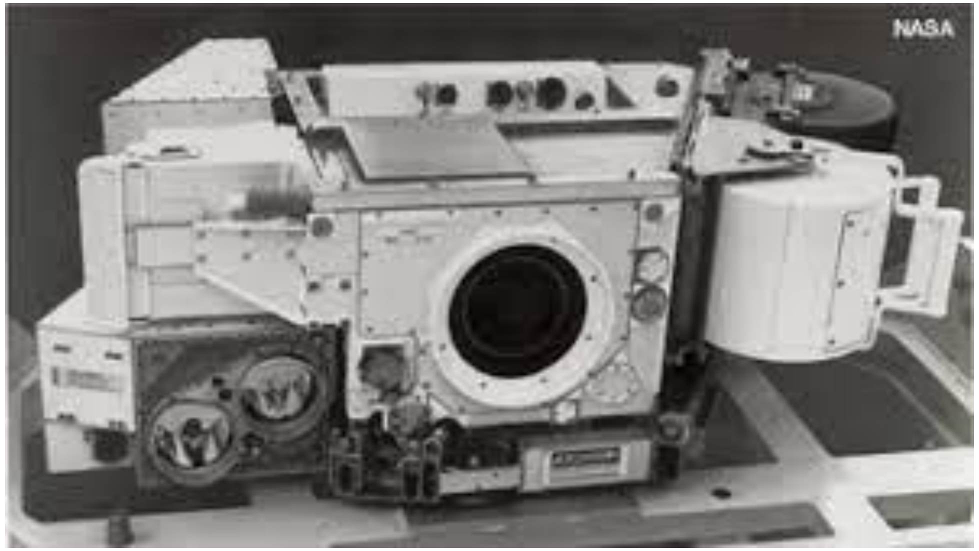
LiDAR

- Lidar has a lot of applications:
  a. agriculture, geography, geology, foresty, seismology
  b. Laser altimetry and guidance
  c. Control and navigation: cars, uas (i.e. helicopter ingenuity in MARS)

- Lidars are based on the application of lasers, an acronym for **Light Amplification by Stimulated Emission of Radiation**.
- Therefore, the first LiDAR-like system was introduced in 1961 by the Hughes Aircraft Company
- This first system was originally called “Colidar” (Coherent light detecting and ranging), and its first terrestrial application was a large rifle-like laser rangefinder produced in 1963 (7 miles range and 15 feet precision, to be used for military targeting)
- Then, LiDAR was started to be used in meteorology (to measure clouds and pollution), and it became “popular” when used in Apollo 15 mission (1971) as laser altimeter to map the surface of the moon

LiDAR





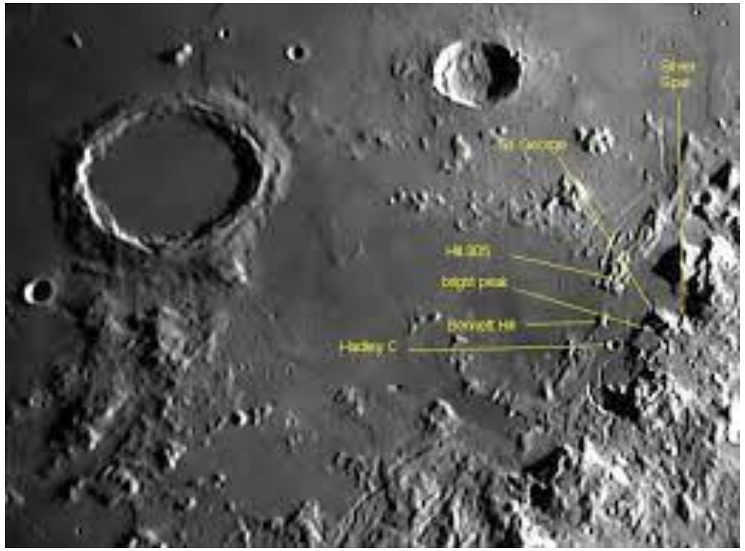


Figure: Left and middle: LiDAR in Space: From Apollo to the future. Right: Apollo 15 Map and Library [Source: NASA].

LiDAR

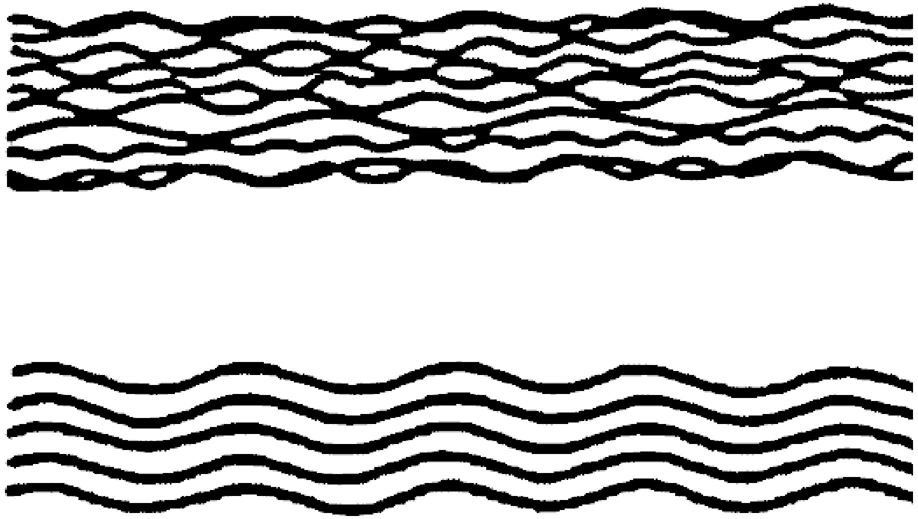
- Lasers produce a narrow beam of light in which all of the light waves have very **similar wavelengths**. The laser's light waves travel together with their peaks all lined up, or in phase. This is why laser beams are very narrow, very bright, and can be focused into a very tiny spot.

- When a **photon is absorbed** by an atom in excited state, it can cause an excited electron to **DROP to a lower energy level and release a new photon**. This phenomena was discovered by Einstein (mathematically)

- In contrast to spontaneous emission that occurs at random energy levels, the liberated energy from stimulated emission creates **a new photon** with a phase, frequency, polarisation, and direction of travel all **identical to the incoming photon**

- For a narrow range of ordinary monochromatic light dominated by a specific color, it is still composed of **many wavelengths** that are **not in phase**.

LiDAR



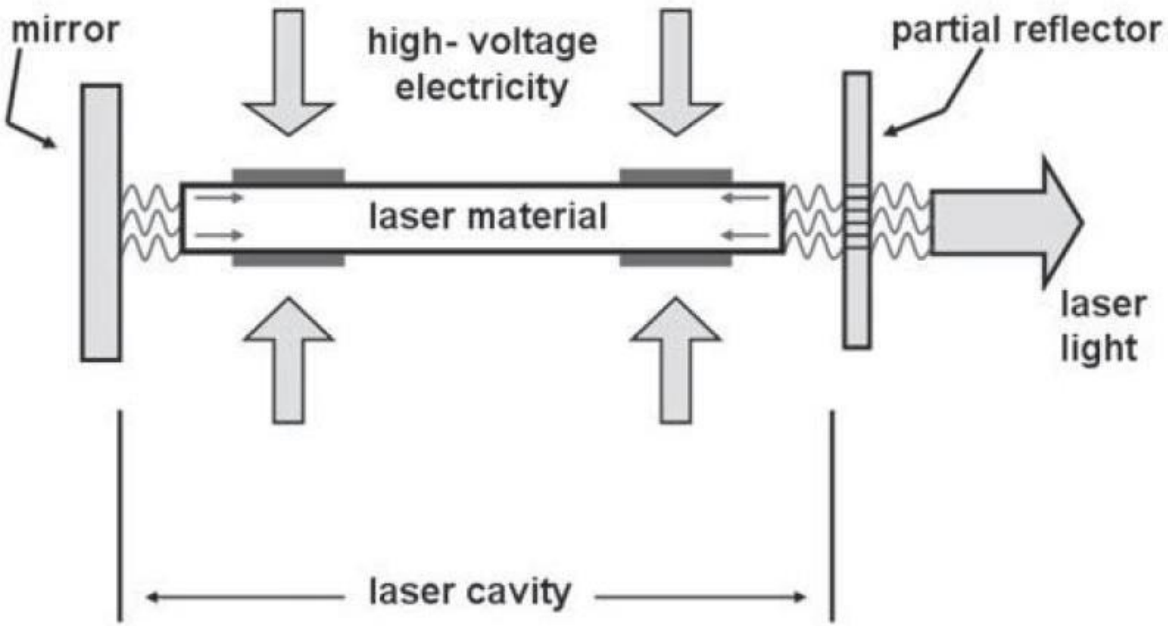


Figure: Left: Normal monochromatic (top) and coherent (bottom) light. Right: Schematic diagram of a simple laser [Campbell, 2011].

- The light from lidars is focused and coherent light with a “pure” wavelength, which consists of **in-phase waves** and can be transmitted over large distances, yet diverges only slightly.

- A simpler laser applies an external energy source (electrical current for instance) to a “lasable” material (usually crystals or gases, such as rubies, CO2 , helium-neon, garon, etc.) to emit coherent light beams. Mirrored surfaces are used to intensity the emitted light.

LiDAR

Laser Material Type	Laser Light Wavelength (nm)
Organic dye dissolved in solvent	300–1000 (tunable laser)
Rare gas ions (e.g., argon ion)	450–530
Helium neon	543 (red), 632.8 (green), 1150 (near-infrared)
Semiconductor	670–680 and 750–900
Nd: YAG	1064 (near-infrared)
Hydrogen fluoride	2600–3000

Figure: Most common laser types and the associated wavelength. "Advances in Environmental Remote Sensing: Sensors, Algorithms, and Applications", **Q. W**, CRC Press (2011).

- Lidars can provide favorable **contrast and resolution** for **three-dimensional mapping**.
- It works at night, but, unlike SAR, it **can not operate through clouds**

LiDAR

- When the laser pulse hits a weak or non-reflective surface. Water, for example, has the tendency to absorb most or all of the near-infrared laser energy directed toward it resulting in either a very weak or absent return

- However……

"Using a new algorithm, **Stanford researchers have reconstructed the movements of individual particles of** light to see through clouds, fog and other obstructions. Like a comic book come to life, researchers at Stanford University have developed a kind of X-ray vision – only without the X-rays.Sep 9, 2020"

https://news.stanford.edu/2020/09/09/seeing-objects-clouds-fog/

LiDAR

- There are two main types of LiDAR
  a. Topographic: It is used mainly in monitoring and mapping topography of a region. So it has its applications in geomorphology, urban planning, landscape ecology, coastal engineering, survey assessment etc.

  b. Bathymetric: Bathymetric LiDARs are used in measuring the depth of water bodies. In a bathymetric LiDAR survey, the infrared light is reflected back to the aircraft from the land and water surface, while the additional green laser travels through the water column. Bathymetric information is crucial near coastlines, in harbors, and near shores and banks. Bathymetric information is also used to locate objects on the ocean floor.

LiDAR

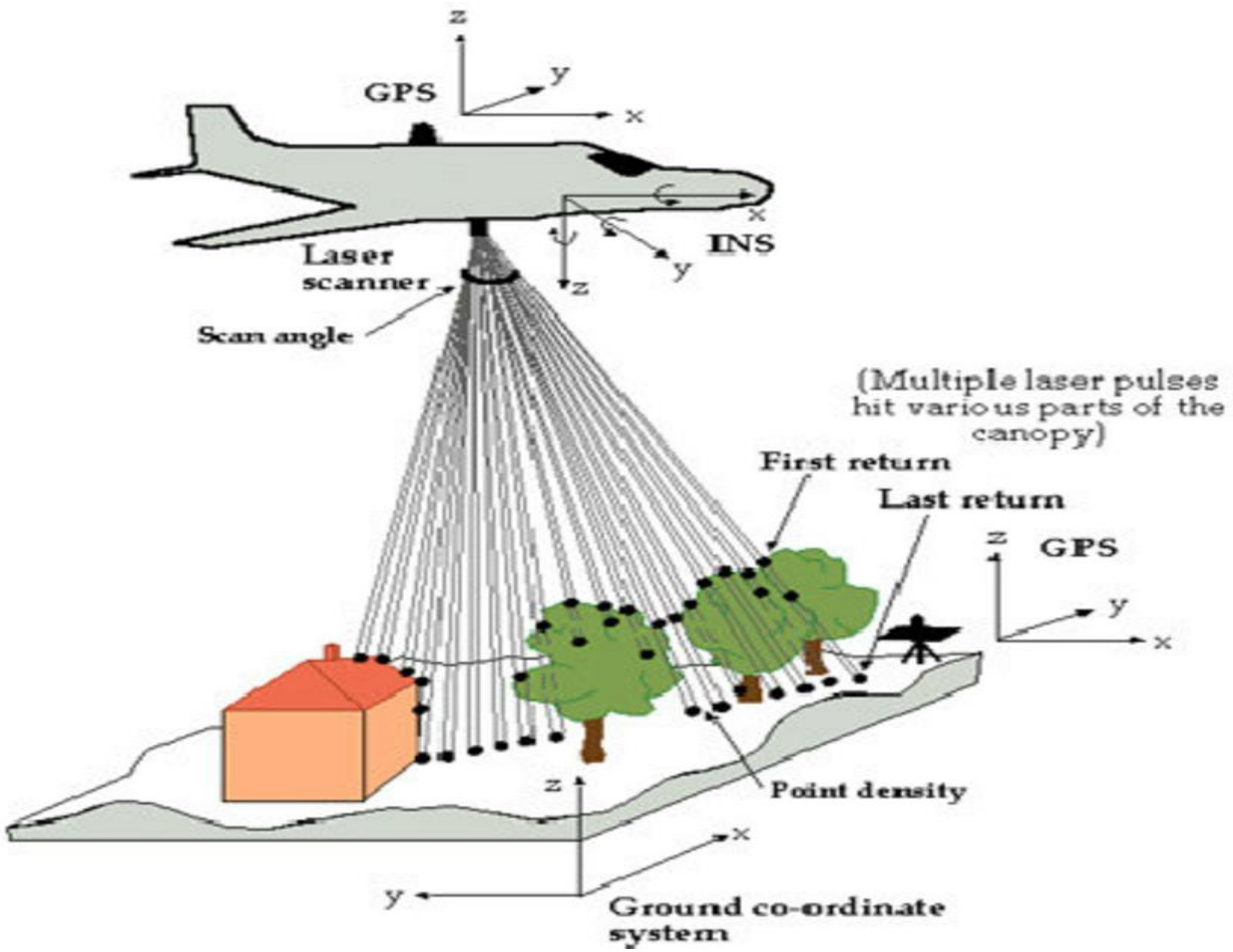


Figure: Illustration of Airborne LiDAR. Source Researchegate.net

LiDAR

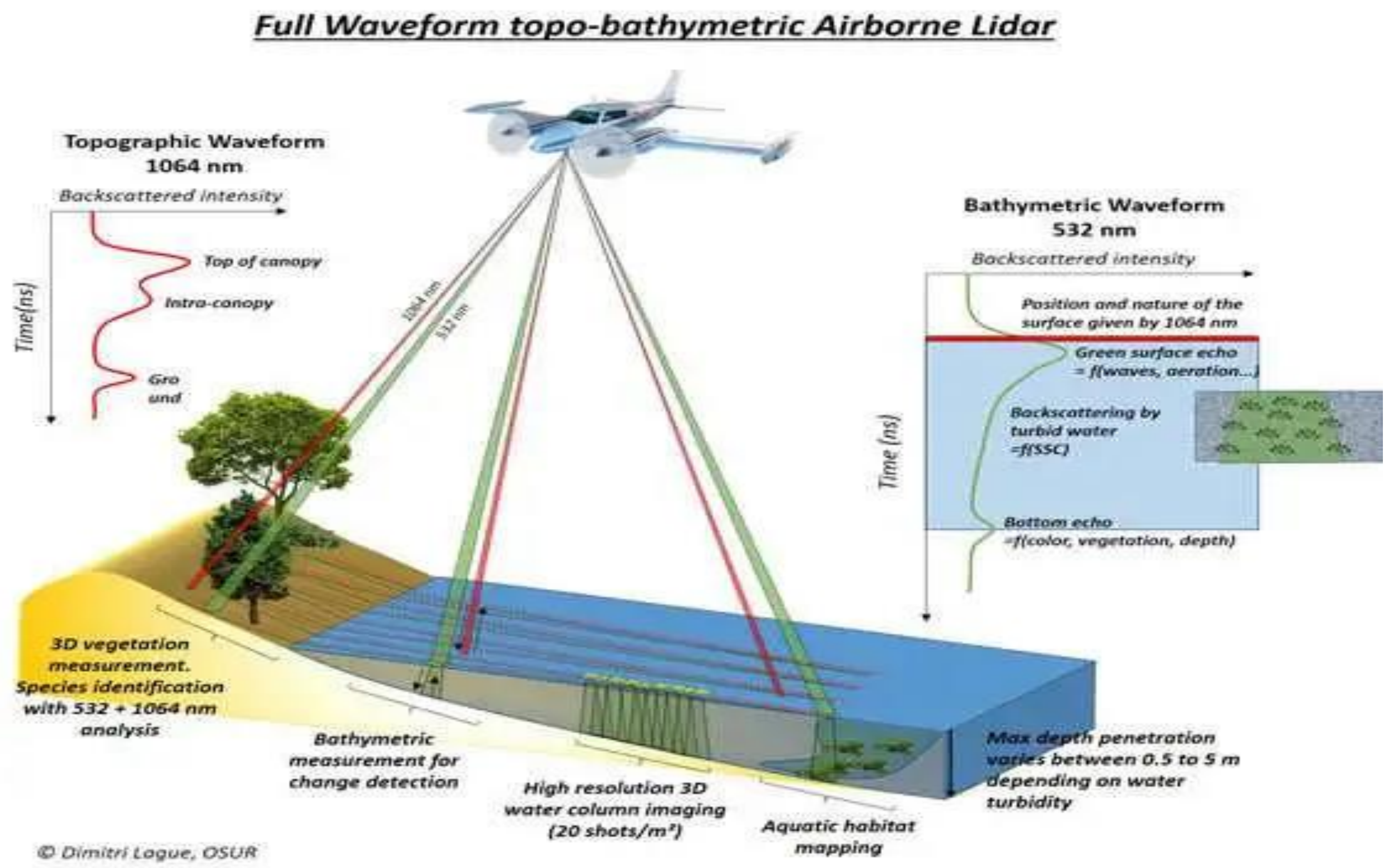


Figure: Topo & Bathymetric Airborne LiDAR. Source Geospatial World

LiDAR

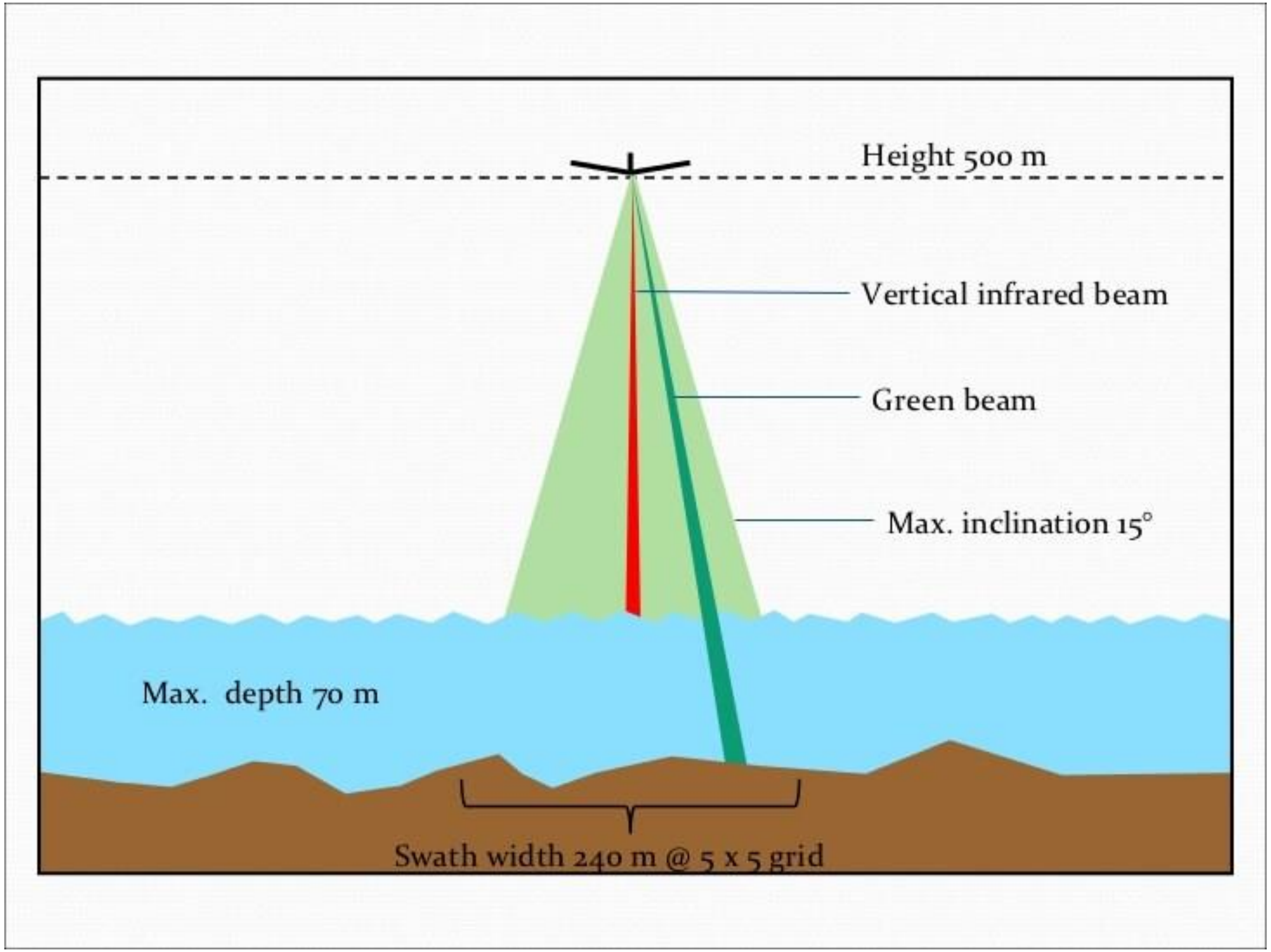


Figure: Bathymetric Airborne LiDAR. Source Geospatial World

LiDAR

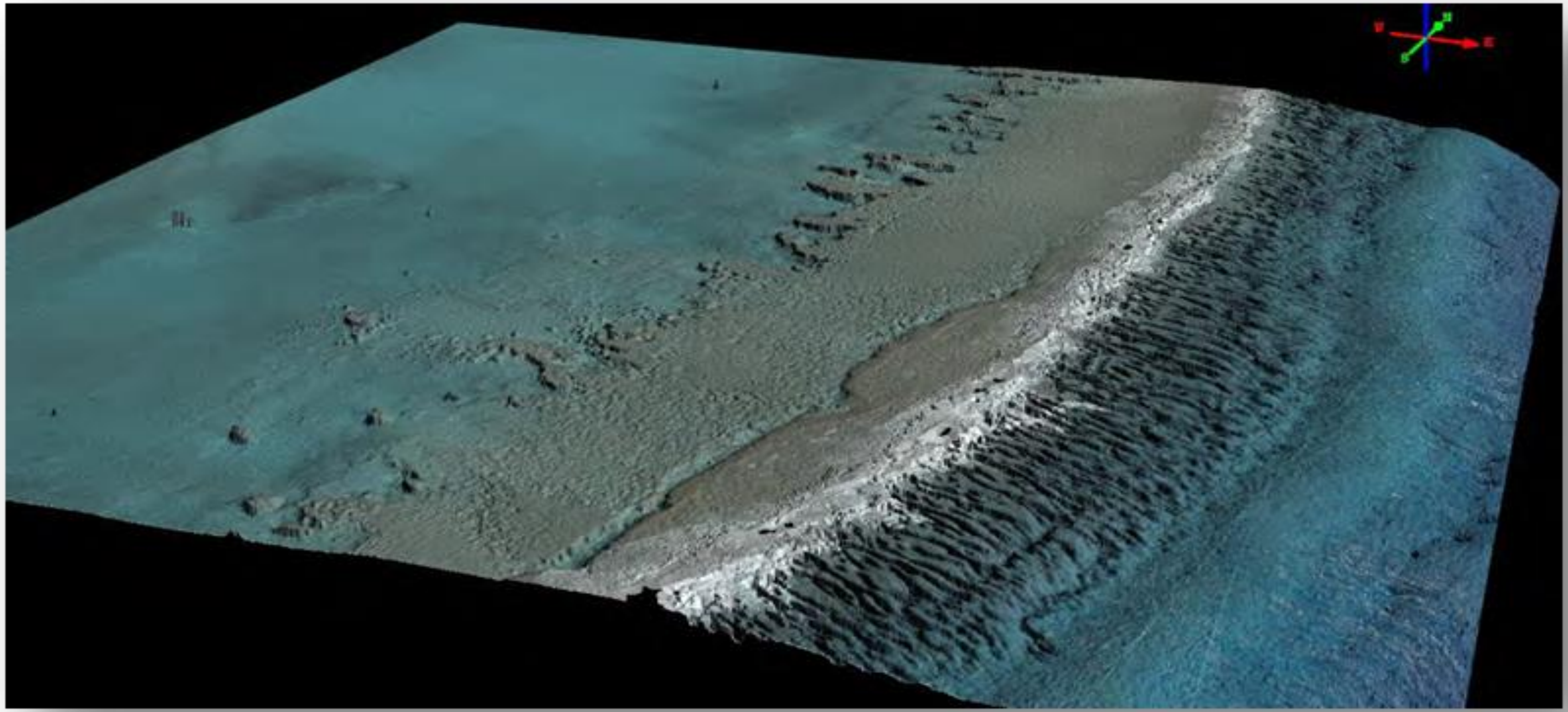


Figure: Bathymetric Airborne LiDAR. Source Geospatial World

LiDAR

- On the threshold of commercial availability are systems called Geiger Mode LiDAR that are able to measure the return of a single photon.

- Geiger-mode LiDAR technology al- lows us to collect elevation data points across large areas of land from **high altitudes** with **high- resolution** results and point densi- ties up to **100 points per square meter** (ppsm).

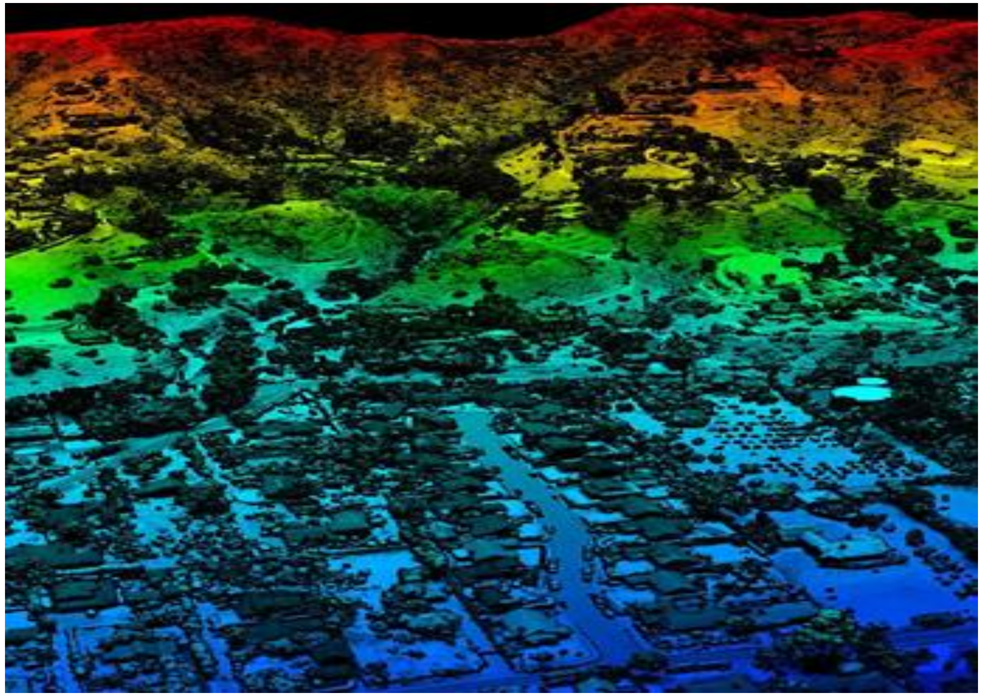


Figure: Geiger LiDAR Image [Source: L3Harris]

LiDAR

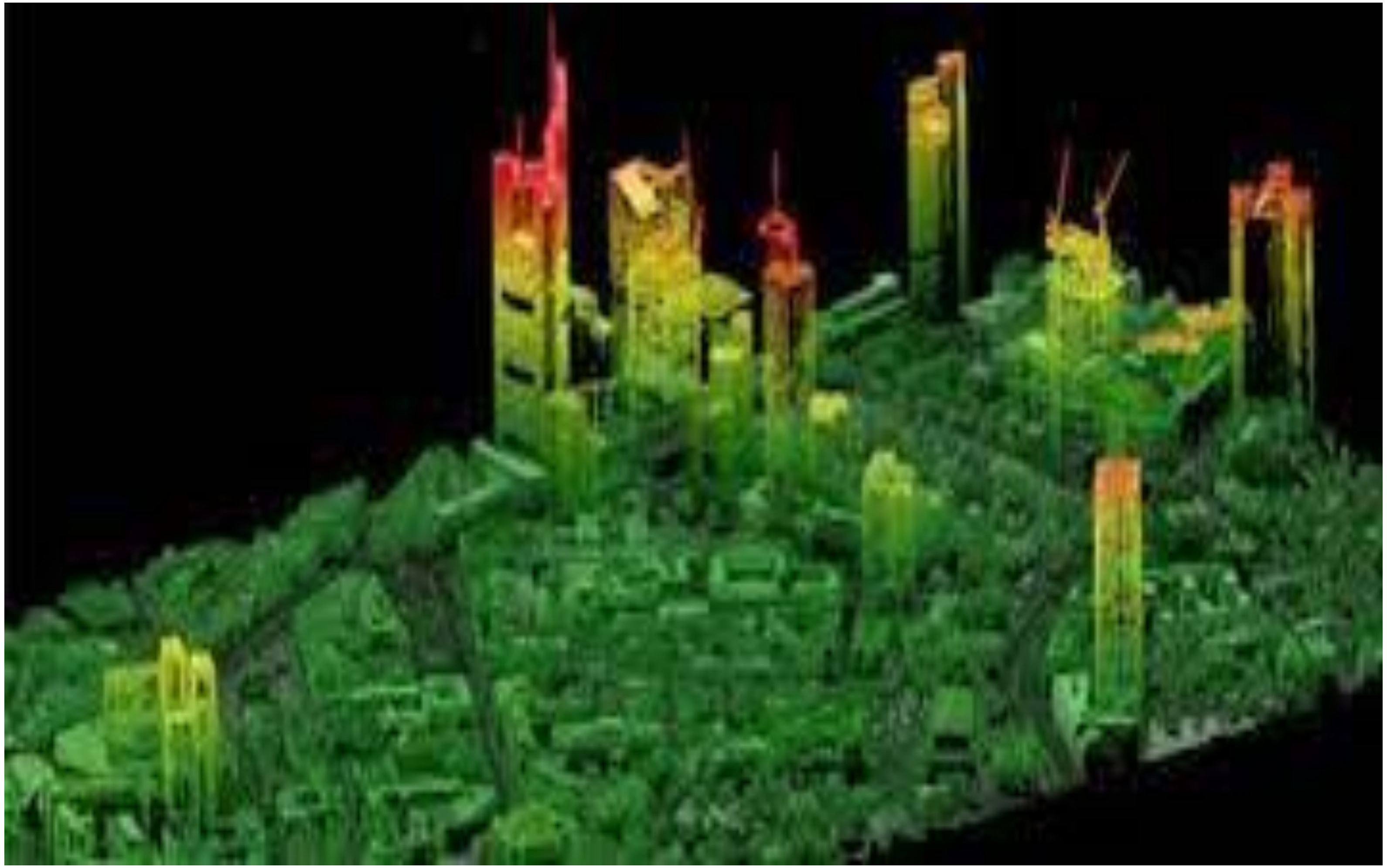


Figure: LiDAR image at Frankfurt [Source: Leica].

LiDAR

Figure: LiDAR image at India [Source: Indiamart].

LiDAR for PRECISION AGRICULTURE

- A March 2013 report from the Association for Unmanned Vehicle Systems International stated that **agriculture was expected to be the largest market application for UASs by a wide margin**.

- Since global food production must cope with the rising global population, new methods for increasing production efficiency and decreasing costs are essential for agriculture.

- Precision Agriculture is a farm management system that utilizes information and technology to enhance the production of the farm.

LiDAR for PRECISION AGRICULTURE

- A March 2013 report from the Association for Unmanned Vehicle Systems International stated that **agriculture was expected to be the largest market application for UASs by a wide margin**.

- Applications of UASs in precision agriculture are numerous and include the following examples:
  - **Crop health assessment**
    - UASs can assist the farmers in the assessment of crop health by remotely **sensing the photosynthetic activity of the plants**, by calculating a **vegetation index**. The most common index is the **Normalized Difference Vegetation Index (NDVI)**.
  - **Stand counts**
    - Most agricultural operations sow a desired number of plants per acre for the maximum yield that the nutrients and soil of the particular field can support. **A UAS can be flown in the early growing season to provide accurate stand counts of the crops that actually emerged**, which can 1) assist the farmer in **making decisions** about whether or not to **replant certain areas**; 2) assist in developing a reasonable expectation for the field's yield for **next year**.
  - **Crop damage assessment**
    - Natural events, such as hailstorms or droughts, may cause significant loss of large quantities of crops. Insurance companies will reimburse the farmer for the lost yield, by comparing the actual yield after damage and the typical yield. A **UAS can verify the extent of widespread crop damage** so that insurance companies can reimburse the farmer for the proper amount of yield loss.

LiDAR for PRECISION AGRICULTURE

- **Vegetation index (VIs)** attempt to measure **biomass or vegetative vigour** based on **digital brightness values**.

- A **VI** is formed from **combinations of several spectral values** that are added, divided, or multiplied in a manner designed to yield a **single value that indicates the amount or vigour of vegetation within a pixel**.

- For a vegetation, there is strong **absorption of red light (R)** by chlorophyll and **strong reflection of infrared (IR) radiation** by mesophyll.

- The **IR/R ratio** can provide a **measure of photosynthetic activity**, which is **high for actively growing plants**.

- One of the most widely used VIs is known as the **normalized difference vegetation index (NDVI)**

$$NDVI = \frac{NIR - RED}{NIR + RED}.$$

LiDAR for PRECISION AGRICULTURE

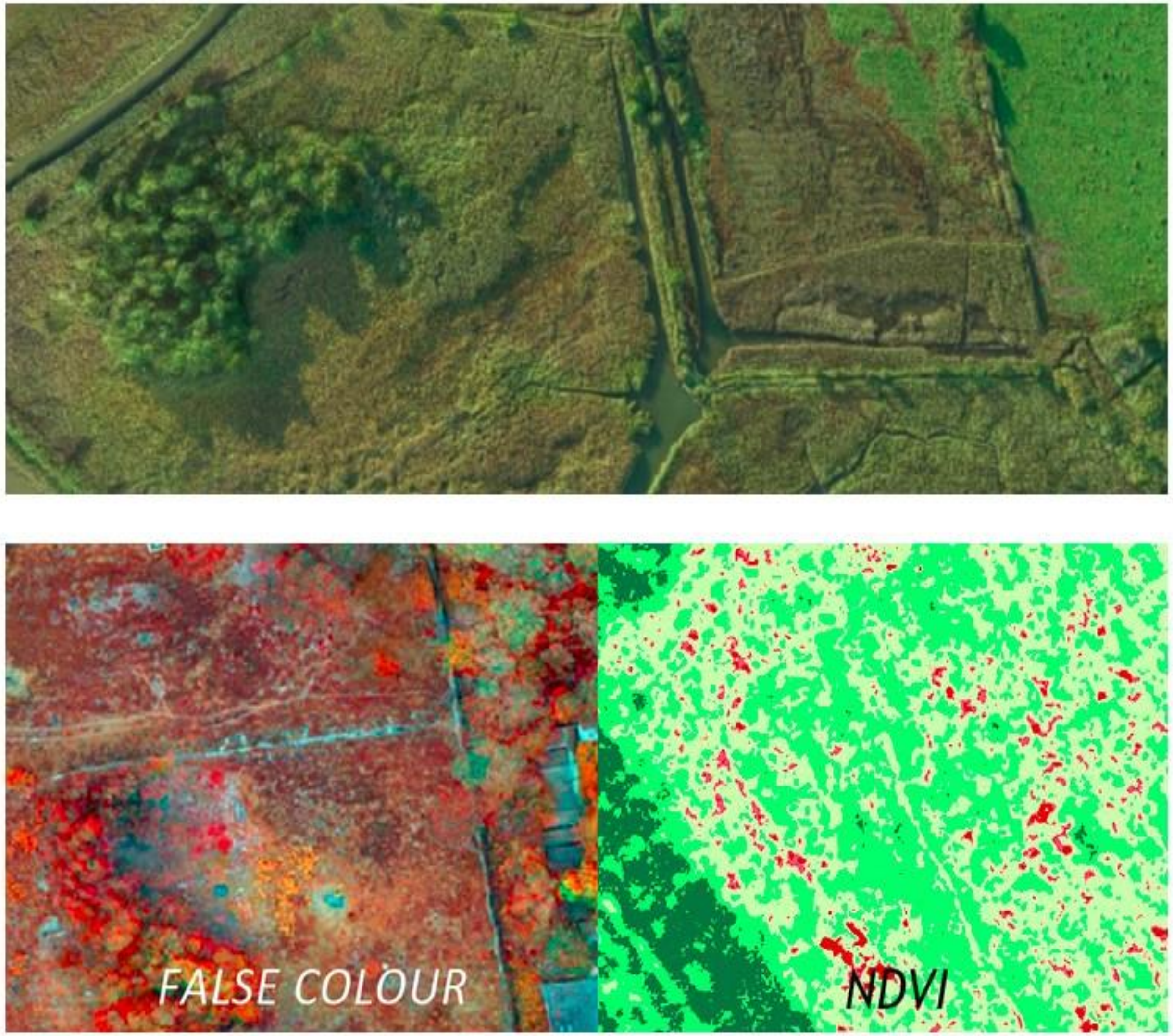


Figure: NDVI map (Source, ➞TerraDrone).

LiDAR for other uses

- **LiDAR in Augmented Reality** : Augmented reality (AR) is a technology that enables the user to view virtual content just like it would have existed in the real world. **LiDAR enhances the clarity and final output of AR systems**. A LiDAR scanner offers high-quality 3D mapping, which permits other AR systems to stack data on top of a high-resolution map. Using point cloud, LiDAR adds to the AR experience. **Research is going on the application of Doppler wind LiDAR, which would allow us to literally see the wind movement clearly**. This approach would be very useful in aviation safety, atmospheric data visualizations, weather forecasting and disaster preparedness

IMAGE

LiDAR for other uses

- **LiDAR in Autonomous vehicles**: Autonomous cars are expected to hit the roads soon and they would revolutionize the automobile sector completely. Without LiDAR, autonomous vehicles are inconceivable. LiDAR should be called the **eye of an autonomous vehicle** as it looks at the surroundings of the vehicle, calculates distance, identifies obstructions ahead, illuminates objects with a laser and then creates a high-resolution digital image. LiDAR is also used **to avoid collisions by measuring the distance between a car and any other car or object in front of it**. The Adaptive Cruise Control system in an autonomous car gets the information from the LiDAR sensors, using which it decides when to apply the brakes, slow down or accelerate.

IMAGE

LiDAR for other uses

- **LiDAR in Climate Change mitigation**: The ultra-high resolution and precise imagery of LiDAR capture and highlight even the minutest details. For this reason, LiDAR is increasingly being preferred by scientists and geologists. LiDAR can help **track deforestation and agriculture patterns** more efficiently than any other method. And the data obtained also pinpoints what was left unobserved in previous estimations, which makes it all the more reliable

- **NASA** has developed a LIDAR-based instrument called GEDI (Global Ecosystem Dynamics Investigation) for the International Space Station that provides a unique 3D view of Earth's forests and helps provide **information about the carbon cycle** that was previously not available. GEDI provides vital information about the impact that trees have on the amount of carbon in the atmosphere. Using the info, the scientists are now able to figure out the exact level of carbon that forests store and the number of trees that should be planted to offset the effect of greenhouse emissions

IMAGE

https://www.yellowscan-lidar.com/es/applications/environmental-research/

LiDAR for other uses

- **LiDAR in Surveying**: Surveying is among the most widely known application areas of LiDAR. LiDAR surveying is used in the fields of construction, urban planning and examining the topography of a region. LiDAR surveying **collects data very fast** and thus is superior to conventional forms of surveying. Spatial models created using LiDAR have a **negligible scope of error margin**, saves a considerable amount of money and improve the final decision making. In surveying, point data is converted into a surface, or **Digital Elevation Model (DEM)**. The DEM can be of any texture depending on the application and density of the data. After the surface is created, analysis can be done, as required.

IMAGE

https://www.yellowscan-lidar.com/es/applications/civil-engineering/

LiDAR for other uses

- **LiDAR in Archeology**: To unearth old archeological sites, LiDAR is proving to be an important asset especially because of extraordinary detailing that it offers. LiDAR saves time as well as the effort of the archeologists and allows them to create models that were almost impossible to create earlier. Stunning 3D images of an ancient Mayan city were created by two archeologists using LiDAR which offers unprecedented insight into that ancient city

https://www.geospatialworld.net/news/teledyne-optech-titan-lidar-enables-discovery-extended-mayan-ruins-guatemala/

https://www.yellowscan-lidar.com/es/applications/archeology/

IMAGE

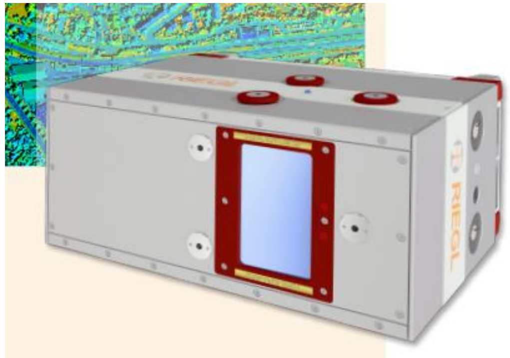
LIDAR for tactical surveillance and intelligence

Topographic Airborne LIDAR for characterization (3D terrain model) of specific locations of interest, focused on Tactical Surveillance and Intelligence

Wide-Area LIDAR sensor collects the data while overflying the area of interest in several overlapping flightlines. The data is stored onboard and processed on ground.

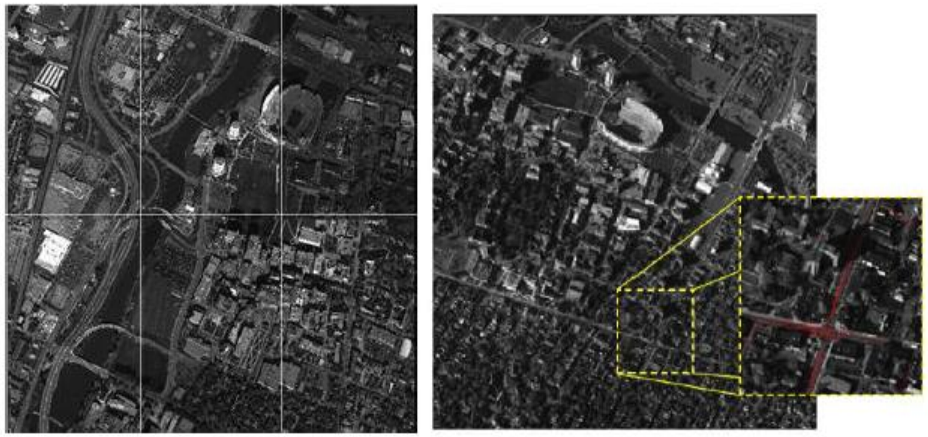
Example: Galaxy T2000 from Teledyne Optech.(Canada)
Size: 340x340x250 mm (Sensor) – 420x330x100 mm (PDU)
Weight: 27 Kg (+ PDU 6,5 Kg)
Power:400W (+28VDC)
Spectral bands: near IR.
Detection distance: 150-6500 m AGL (above ground level)

Example: VQ-780 II from RIEGL.(Austria)
Weight: 20 Kg
Spectral bands: near IR.
Detection distance: up to 5600 m above MSL (mean sea level)



WAMI for tactical level persistent surveillance

Wide-area motion imagery (WAMI) is an approach to surveillance, reconnaissance and intelligence that exploits very wide field of view/high resolution cameras to detect, locate, and track targets in a very wide area of interest.



The WAMI sensors produces imagery of the entire coverage area in real time at a low frame rate**. By analyzing such a big area the exploitation of the sensor is focused in stablish normal patterns and detect out layers to those patterns.**

Ground sample distance (GSD) is the parameter to measure the resolution of the sensor.

Example: Redkite Pod. (USA)
Weight: 16 Kg. + 113 Kg (GCS)
Pod Power: 300W.
Resolution GSD: 0.5 m@12 kft.
Footprint 4km diameter

Example: PSI Vision 3000. (Canada)
Weight: < 100 Kg (50 Sensor + 50 PSU)
Power: 450W (Sensor) + 1500W (PSU)
Resolution GSD: 20 cm @ 10 kft; 40 cm @ 20 kft
Footprint 4,5 km x 3,8 km

Multi-/Hyperspectral Sensor for IEDs and Camouflage

Detection of camouflaged objects and Improvised Explosive Devices using hyperspectral imaging sensors and spectral bands analysis.

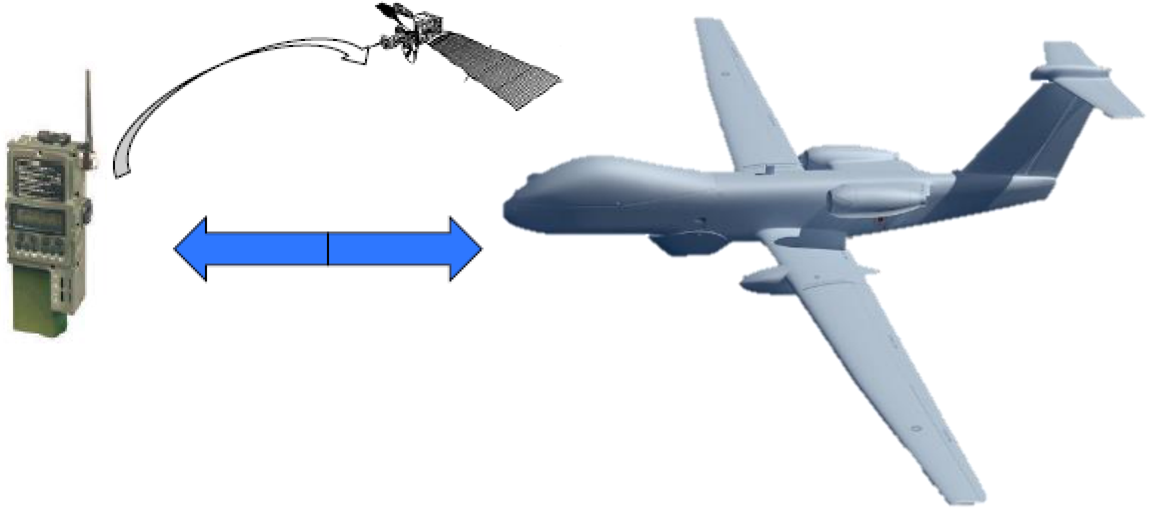
Example: Aisa Fenix from Specimen (Finland).
Weight: < 23 Kg (Sensor) + 10 (DPU)
Size: 530x530x210 mm (Sensor) – 300x260x195 mm (DPU)
Power: 500W (Sensor)
Resolution GSD: 1 m @ 4500 kft;
Swath width: 0,73 x altitude

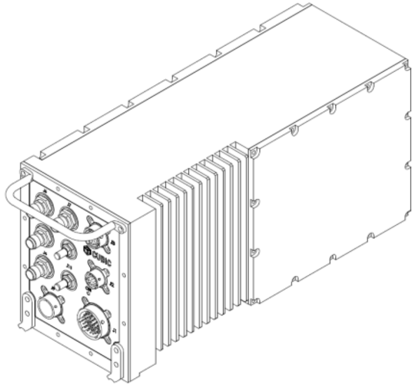
specim
SPECTRAL IMAGING

Georectified AisaFENIX image

PLS (Personal Locator System)

- PLS stands for Personal Locator System, used for SAR and CSAR
- The PLS is designed to perform the following functions:
  - ✓ Locate radio signals from compatible Survival Radios, providing range/bearing (AME/DME) and/or GPS.
  - ✓ Exchange text messages between the PLS and the ground Survival Radios.
  - ✓ Allows voice communications (radio comms) between the PLS and the ground Survival Radios.



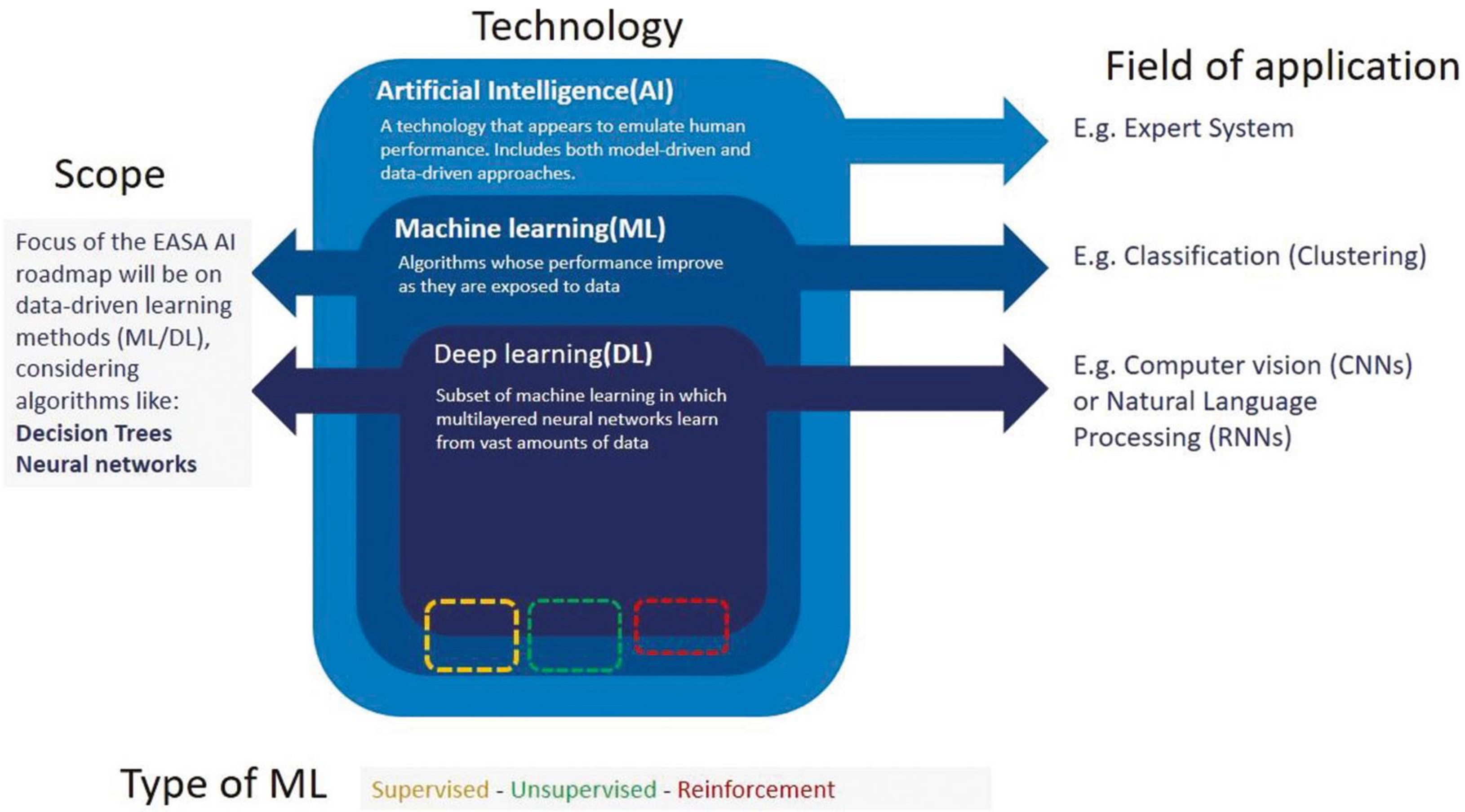


AUTONOMOUS FLIGHT

1. What is Artificial Intelligence?

The capability of a machine to match or exceed intelligent human behavior

1. AI Taxonomy



1. What is Artificial Intelligence Today?

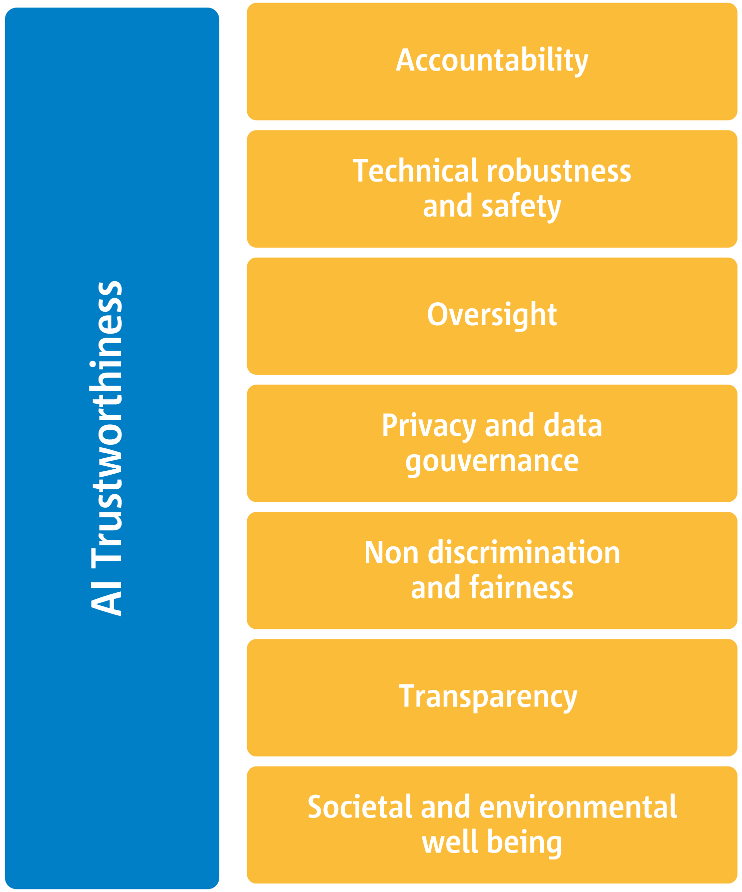
The capability of a machine to match or exceed intelligent human behavior by training a machine to learn the desired behavior

2. What are UAS AI challenges?

- Traditional development assurance frameworks are not adapted to machine learning
- Difficulties in keeping a comprehensive description of the intended function
- Lack of predictability and explainability of the ML application behaviour
- Lack of guarantee of robustness and of no ‘unintended function’
- Lack of standardised methods for evaluation of the operational performance of the ML/DL applications
- Issue of bias and variance in ML applications
- Complexity of architectures and algorithms
- Adaptive learning processes

2. Trustworthiness

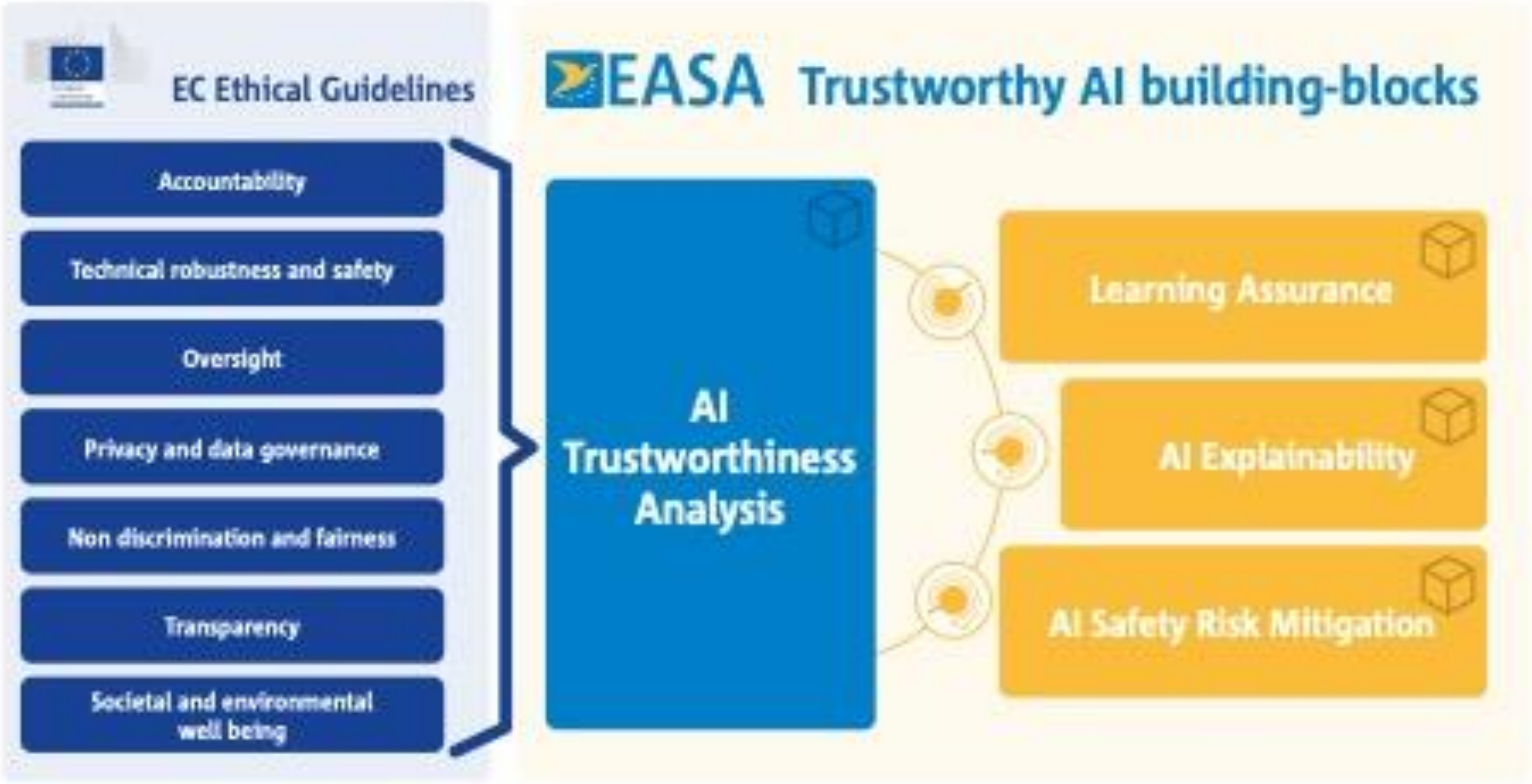
EU High-Level Expert Group (HLEG) Artificial Intelligence (AI)



2. Possible AI/ML Classification

Level 1 AI/ ML : assistance to human	Level 2 AI/ ML : human/ machine collaboration	Level 3 AI/ ML : more autonomous machine
• Level 1A – Routine assistance • Level 1B – Reinforced assistance	• Level 2A – Human performs a function / Machine monitors • Level 2B – Machine performs a function / Human monitors	• Machine performs functions with no human intervention in operations. Human is in the loop at design and oversight time

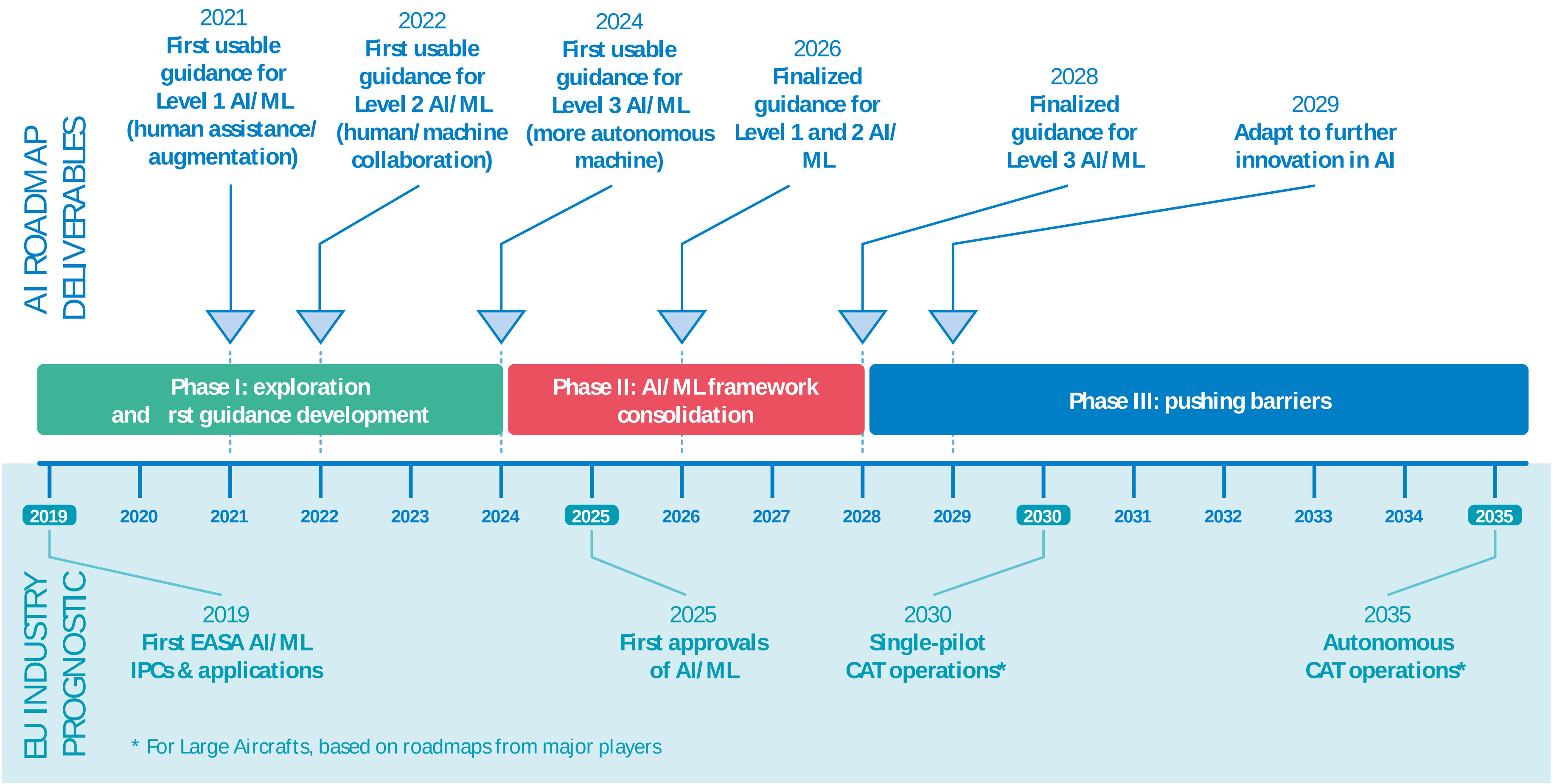
2. Aviation Trustworthy AI



2. Objectives

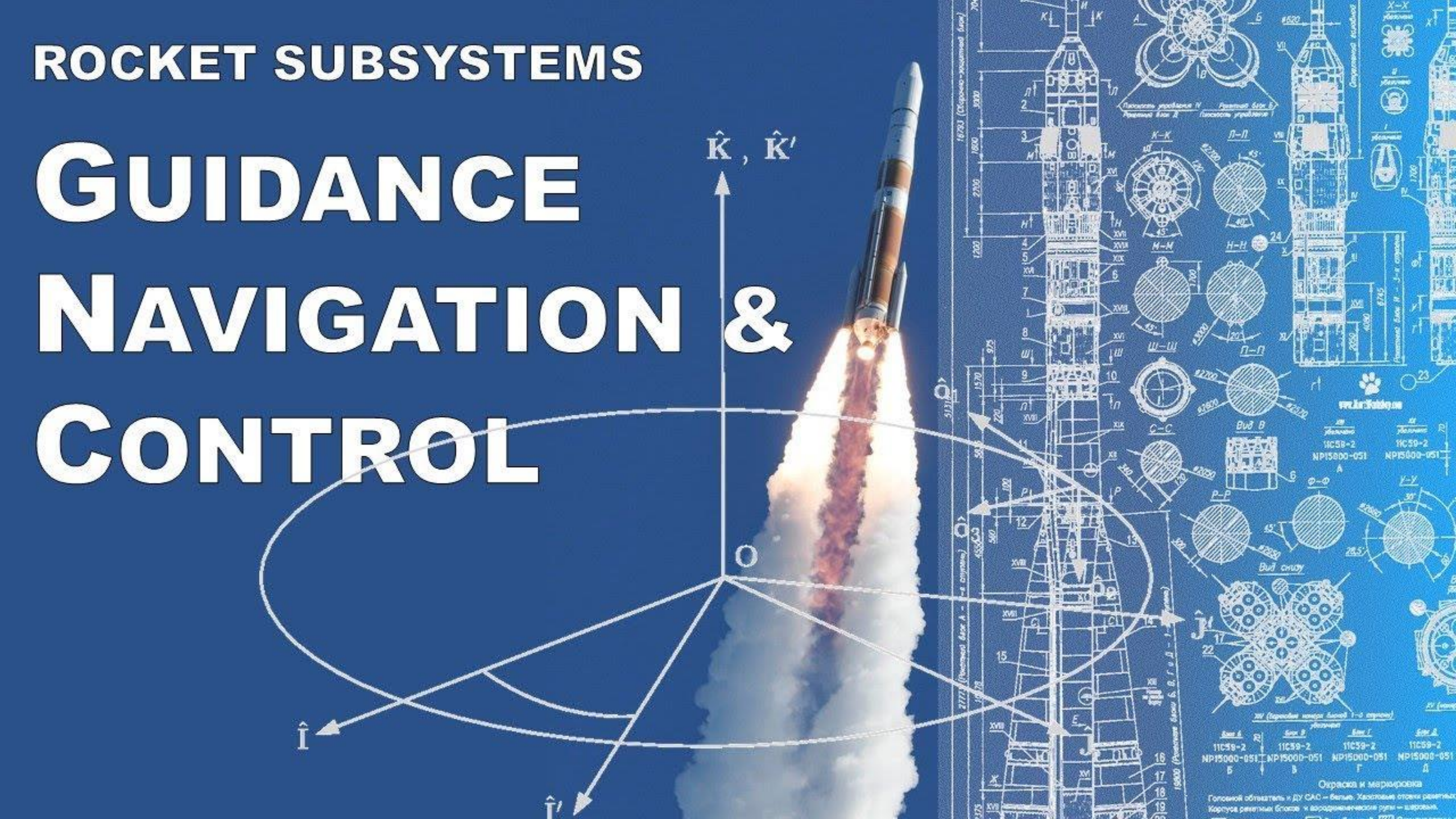
1. Develop a human-centric AI Trustworthiness framework
2. Make EASA a leading certification authority for AI
3. Support European Aviation leadership in AI
4. Contribute to an efficient European AI research agenda
5. Contribute actively to EU AI strategy and initiatives

2. Roadmap


AI ROADMAP DELIVERABLES
2021
First usable guidance for Level 1 AI/ML (human assistance/ augmentation)
2022
First usable guidance for Level 2 AI/ML (human/machine collaboration)
2024
First usable guidance for Level 3 AI/ML (more autonomous machine)
2026
Finalized guidance for Level 1 and 2 AI/ ML
2028
Finalized guidance for Level 3 AI/ML
2029
Adapt to further innovation in AI
Phase I: exploration and rst guidance development
Phase II: AI/ML framework consolidation
Phase III: pushing barriers
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
EU INDUSTRY PROGNOSTIC
2019
First EASA AI/ML IPCs & applications
2025
First approvals of AI/ML
2030
Single-pilot CAT operations*
2035
Autonomous CAT operations*
* For Large Aircrafts, based on roadmaps from major players

3. What is Autonomous Flight?

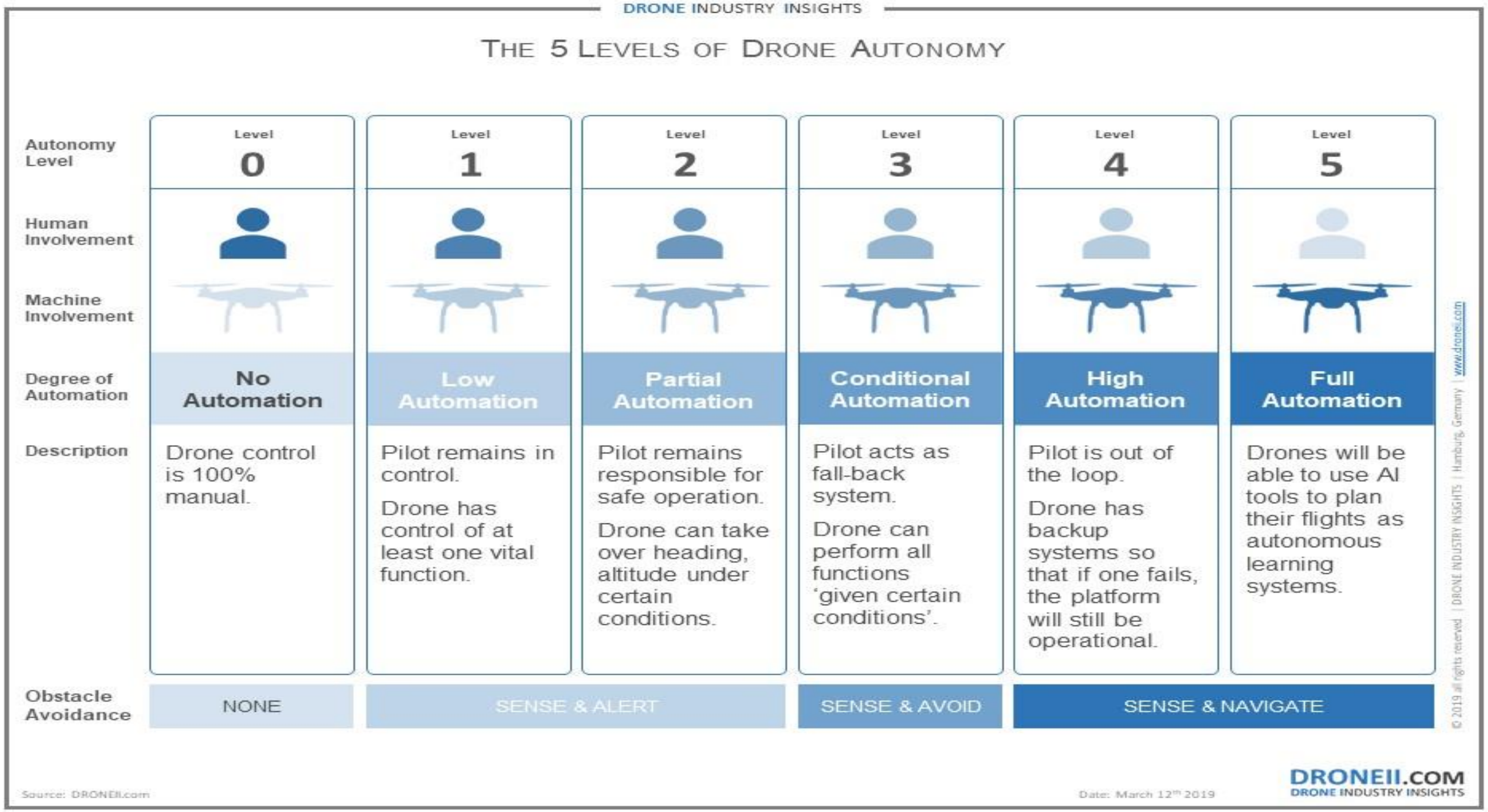
Flight capability of an aerial machine without human intervention


ROCKET SUBSYSTEMS
GUIDANCE
NAVIGATION &
CONTROL

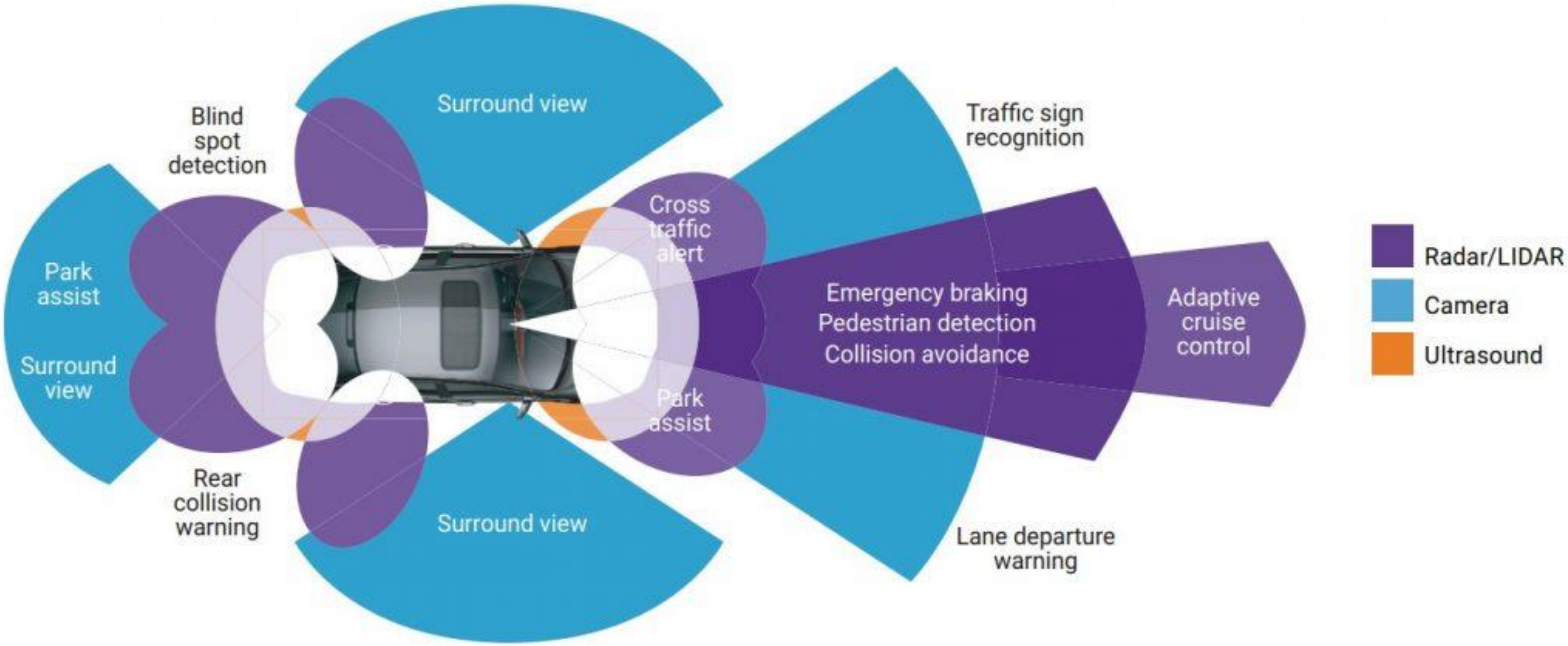
3. Different Concepts?

Autopilot	Fly-by-wire	ATOL
Guidance	Navigation	Control
Mission	Collision Avoidance	Self-Flying

3. Levels of Autonomy



3. Sensor Fusion




AIRBUS
BY AIRBUS


AIRBUS
D-HCIA


EXPERIMENTAL


AUTONOMOUS
FLIGHT


N221HV

URBAN AIR MOBILITY

UAM is a solution for cities

[Airbus Amber]

UAM is a solution for ~~cities~~ citizens

Emerging technologies

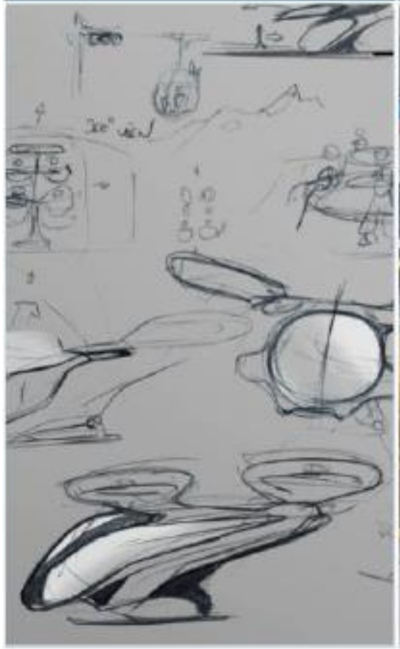
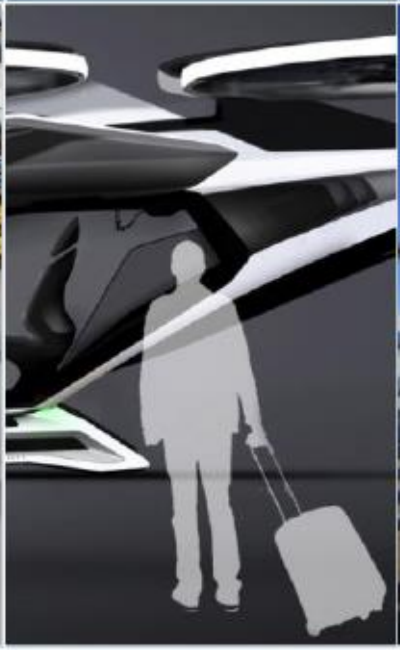
New business models

Change in people needs

Urban Air mobility brings **new solutions** to support **transportation needs in cities** and urban areas by enabling a **safe**, **quiet**, **sustainable** and **eco-friendly** use of the **third dimension**.

AIRBUS

Need to ensure value chain is success-ready

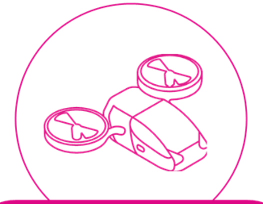
Urban Aircraft	Support & Service	Flight Operations	Air Traffic Management	Ground Infrastructure	Passenger Solution
					
Design, Development and Production	Maintenance, Repair, Overhaul Spare parts	Operation of the Urban VTOL Acquisition or leasing of VTOL	Develop and operate ATM/UTM solution for Urban VTOL	Installation and maintenance of VTOL pads	Booking application for flight trips

Need to ensure value chain is success-ready

The Vision: Global Airspace in 2050

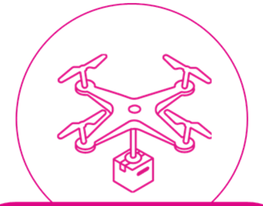
Traffic Growth

Environmental impact



New Vehicles

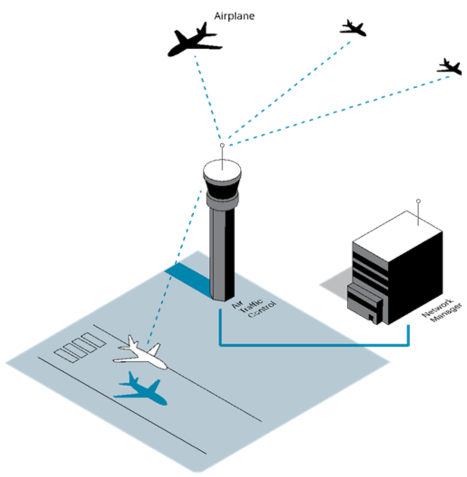
New vehicles (eVTOLs, HAPS)



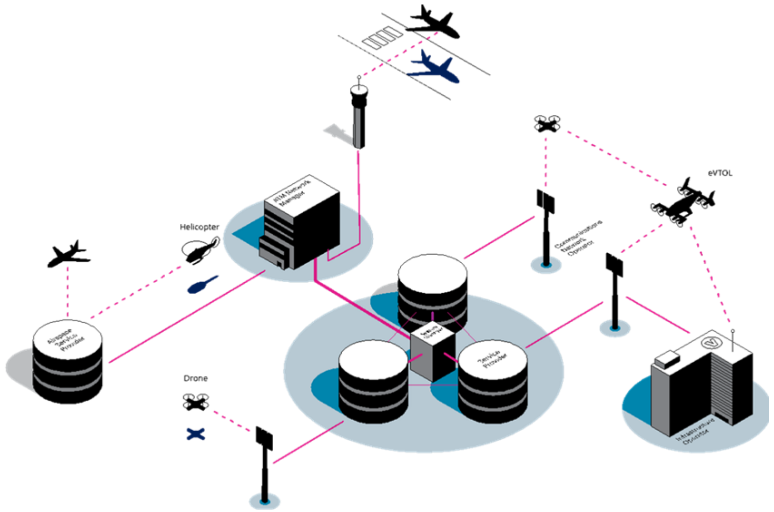
Autonomy

BVLOS, UAM, Fleet Operations

- **UAS (Unmanned Aircraft Systems) Traffic Management (UTM)** is a digital and automated traffic management ecosystem to enable new types of aerial operations
- Autonomous drone operations and Urban Air Mobility (UAM) will require a set of services the current ATM system is not able to provide
- UTM aims at enabling safe and efficient airspace access for **new entrants**, facilitating new operations and contributing to extend and eventually transform the ATM system



Traffic Management Today



Traffic Management Tomorrow

ICAO Definition - UTM principles and challenges

"The aim of UTM is the safe, economical and efficient management of UAS operations through the provision of facilities and a seamless set of services in collaboration with all parties and involving airborne and ground-based functions. Like ATM, a UTM system would provide the collaborative integration of humans, information, technology, facilities and services supported by air, ground and/or space-based communications, navigation and surveillance." ICAO

MAIN PRINCIPLES

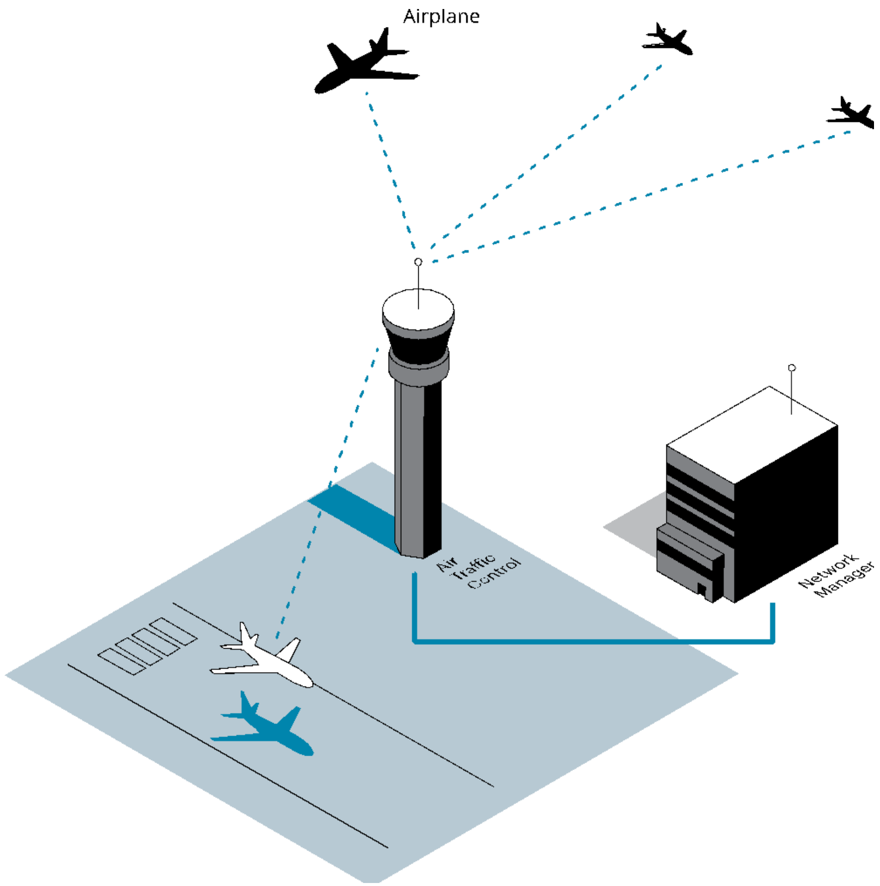
- Regulator oversight.
- Fair airspace access.
- Priority to public safety operations.
- UAS/operator qualified to airspace requirements.
- Safety culture.

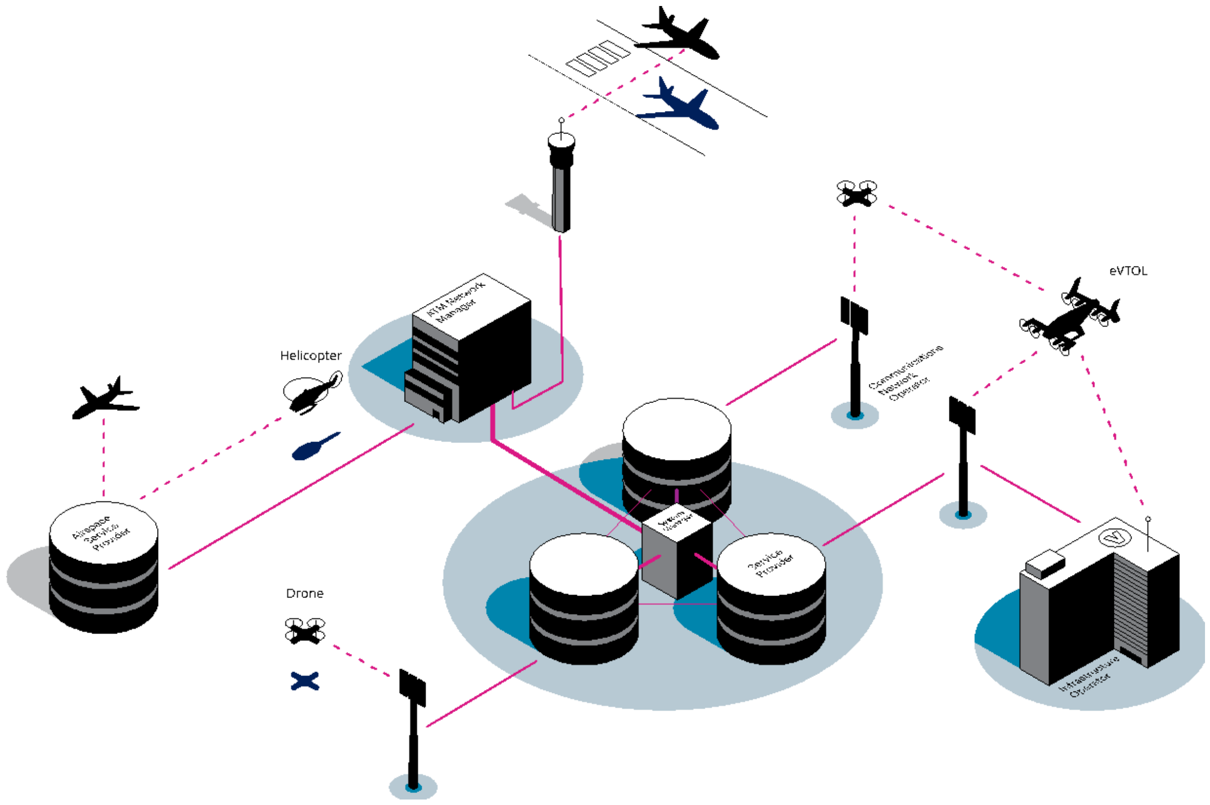
SERVICE-BASED ARCHITECTURE

UTM is still in its e**arly development stages**.

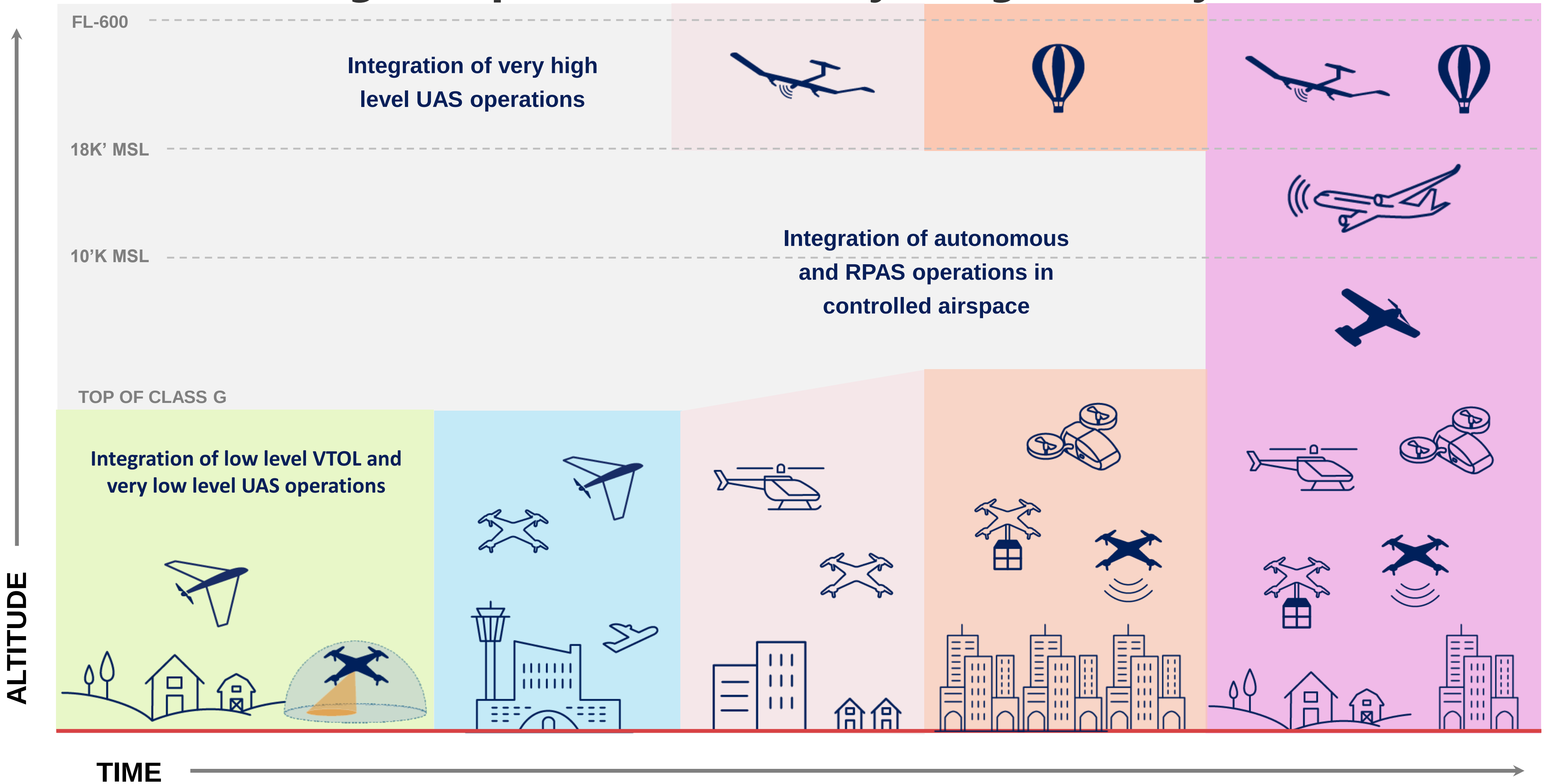
Major **challenges** are identified in areas impacting airspace classification and access, regulation and standards, rules of the air, liability and insurance, certification, ATM integration CNS, meteo, conflict resolution, etc

Traffic Management Today → Traffic Management Tomorrow





Autonomous & Digital Operations In a Fully Integrated Sky



EASA regulation on services

Regulatory framework is COMMISSION IMPLEMENTING REGULATION (EU) 2021/664 of 22 April 2021 on a regulatory framework for the U-space to be inforce by January 2023 (AMC / GM under development)

Overview

- Regulation sets out provisions applicable to three entities: UAS operators, U-space Service providers (USSP), providers of common information services (CIS)
  - Exclusion of State operations, Model clubs, small aircraft <250g ('open') and IFR flights
- MS may designate UAS geographical zones as U-space airspace
  - Airspace risk assessment (safety and security risks)
- 4 mandatory U-space services:
  - network identification;
  - geo-awareness service;
  - UAS flight authorisation;
  - traffic information;

EASA

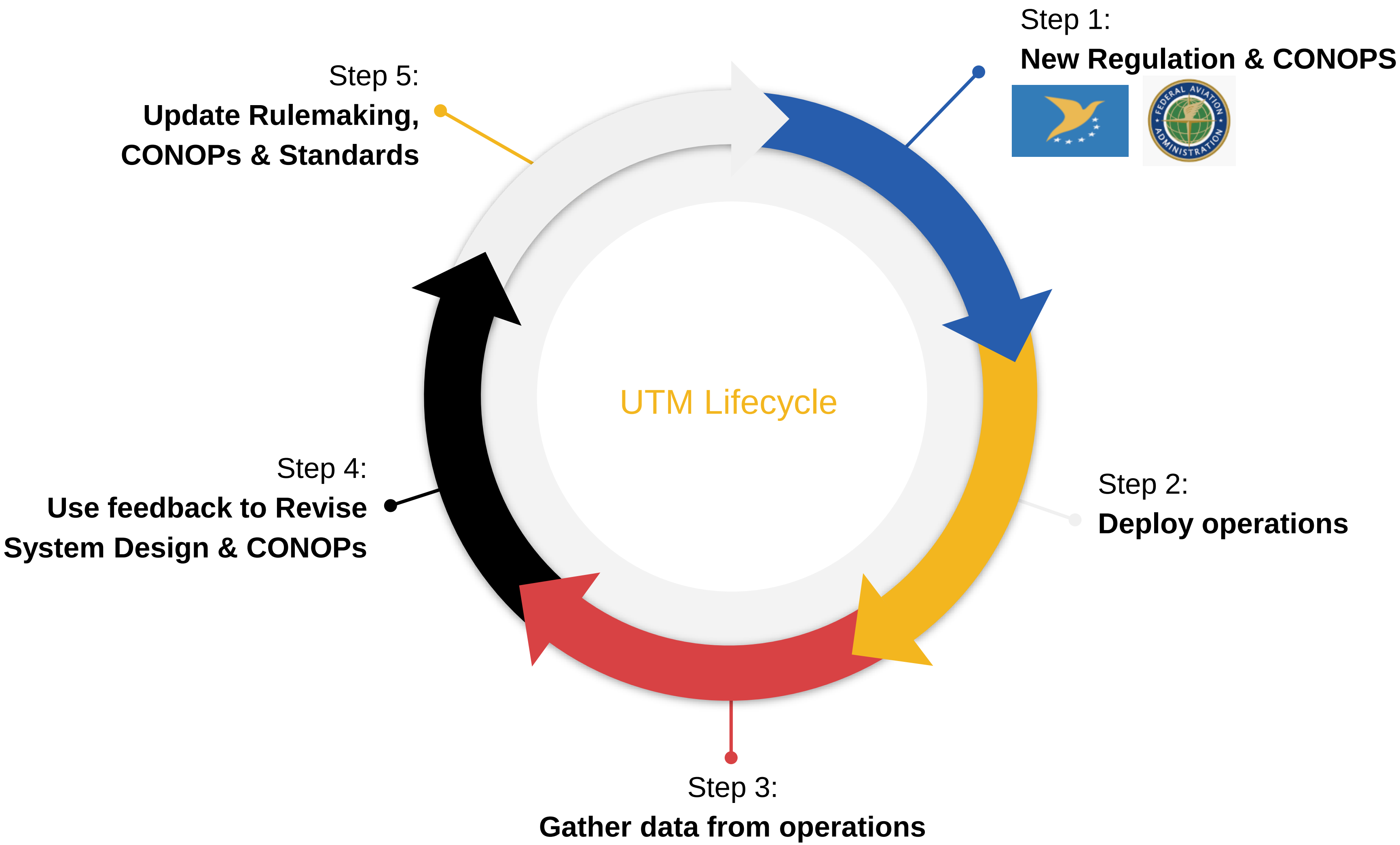
Overview

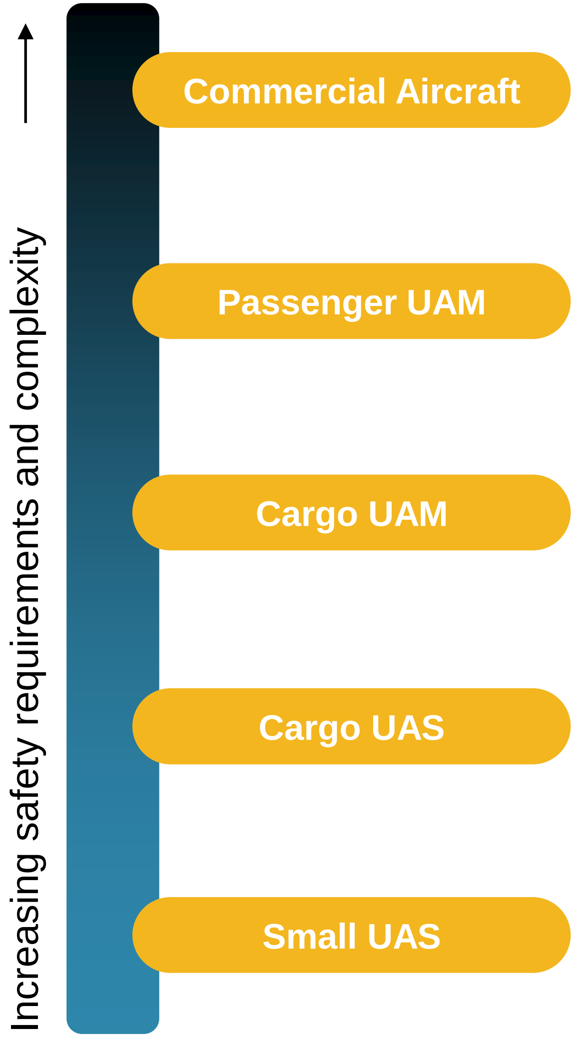
- 2 optional U-space services:
  - Weather information and Conformance monitoring;
- Certification of USSPs and Single CIS provider including safety management systems;
- UAS operators must comply with R2019/947
- UAS operators providing U-space services are USSPs
- USSPs provide a strategic deconfliction service to UAS operators
- ANSPs responsible for manned aviation:
  - In controlled airspace - dynamic reconfiguration of the airspace
  - In uncontrolled airspace - electronic conspicuity
- ANSPs and USSPs exchange information through the single or decentralised CIS

EASA

8

Evolution to Digital ATM





SENSE AND AVOID

Sense & Avoid - Functional Analysis

- *Surveillance Functions*

***1) Observation of aerospace**: traffic, surface areas, obstacles, weather, etc by visual, aural, electronic or other means to detect the surrounded hazards. Within this information the pilot is able to take the appropriate actions to manage the flight.*

***2)** Provide **own aircraft identification** and data (aircraft position, altitude, etc) to the external world (to Air Traffic Control, ATC, and surrounded traffic).*

IMPACT

Type of Operation

- *Segregated Airspace*
- *Non-Segregated Airspace*
  - *Controlled Airspace (VFR/IFR)*
  - *Non-Controlled Airspace (VFR/IFR)*
  - *U-Space (under definition)*
- *Civil Environment*
- *Military Environment*
- *On Ground / In Flight*

In an RPAS the Pilot is not on board the A/C, is on ground controlling the RPA from the RPS.

→ PILOT CAN NOT SEE AND AVOID

SENSE AND AVOID

Sense & Avoid - Functional Analysis

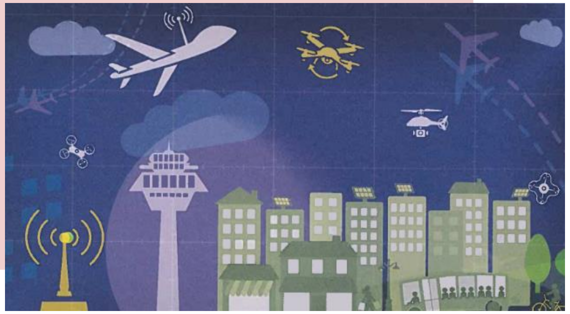
- *Surveillance Functions*

<table>
<tr><th></th><th>Segregated</th><th>Non-Segregated</th></tr>
<tr><td rowspan="2">Aircraft Identification & Data</td><td colspan="2">Required: Modes A, C and Elementary Mode S (ELS) (MTOW<=5700Kg & Max.True Airspeed <= 250kts)
Required: Enhanced Mode S (EHS) and ADS-B* (MTOW>5700Kg OR Max.True Airspeed > 250kts)
*TBC if ADS-B is mandated for Segregated Airspace. → It is suitable for better Situation Awareness.</td></tr>
<tr><td colspan="2">Military Environment: Modes 1, 2, 3, and Crypto 4, 5 for battelfield</td></tr>
<tr><td>Terrain/Obstacles Detection</td><td colspan="2">To Be Analyzed if it is required, it depends on the RPAS Concept of Operation.
- It can depend on the class of airspace the RPAS is going to operate, if the operation is performed over populated/scarcely/non-populated areas, etc
- To improve the situation awareness.
- Option: mission preparation taking into account maximum terrain and obstacles elevation, defining a Minimum Altitude Limit to avoid such hazards.</td></tr>
<tr><td>Weather Hazards Detection</td><td colspan="2">To Be Analyzed if it is required, it depends on the RPAS Concept of Operation.
- It can depend on the class of airspace the RPAS is going to operate, the duration of the mission, etc
- To improve the situation awareness.
- Option: mission preparation taking into account weather information, or weather information provided to the pilot during the mission.</td></tr>
<tr><td>On Ground</td><td colspan="2">- To Be Analyzed if it is required, it depends on the RPAS Concept of Operation On Ground.
- Additional situational awareness and Traffic and Obstacles detection could be required during ground operation: Taxi, Take-off and Landing.</td></tr>
</table>

Sense & Avoid - Functional Analysis

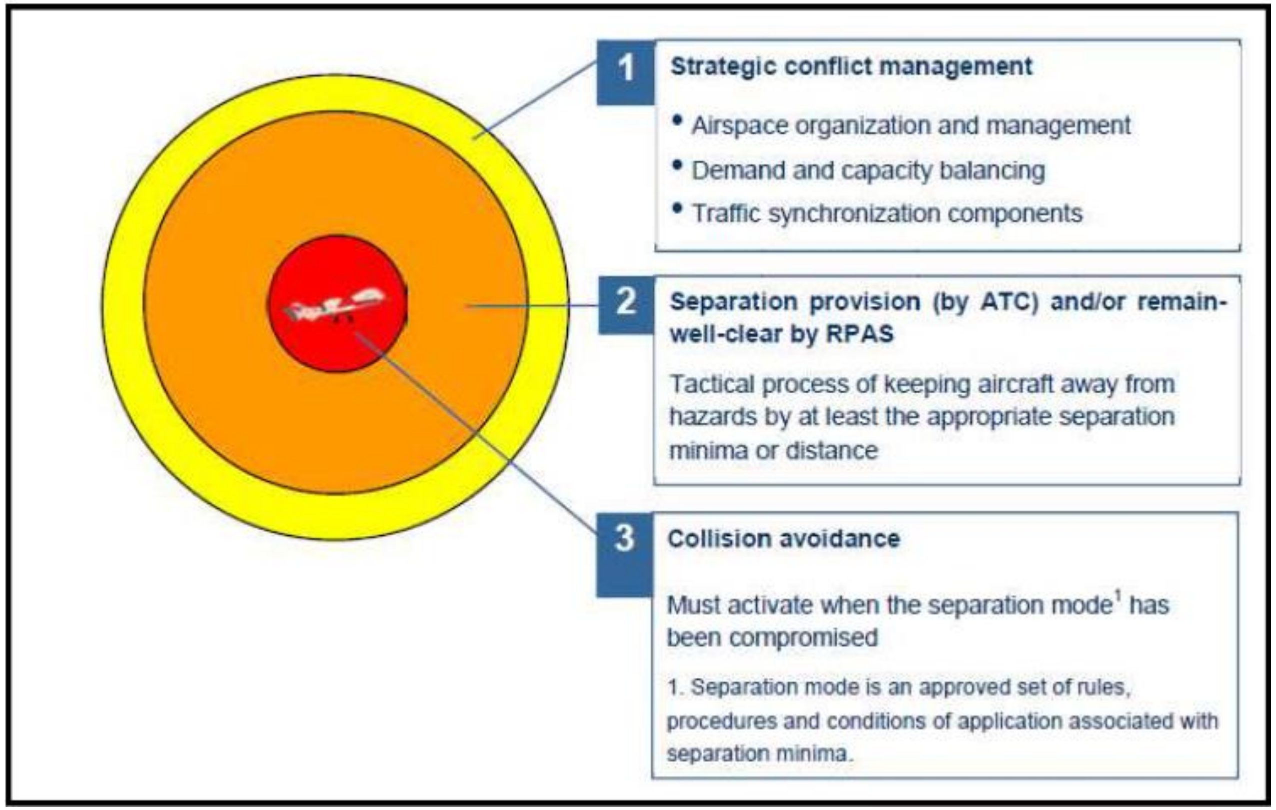
- *Surveillance Functions*

Traffic Detection	**Segregated Airspace**	Not required: Other traffic is not allowed to operate in this volume	
	Non-Segregated Airspace	CONTROLLED AIRSPACE Controlled Airspace by ATC Class A: Only IFR traffic Class B: IFR & VFR traffic Class C: IFR & VFR traffic *Separation Responsibility*: ATC *Collision Avoidance Responsibility*: - The pilot, with autonomous capability of RPA - ATC has to be informed	NON-CONTROLLED AIRSPACE Airspace can be controlled or not by ATC Classes D, E, F, G: VFR & IFR traffic *Separation Responsibility*: - Controlled Airspace: ATC - Non-Controlled Airspace: Pilot - ATC information when available *Collision Avoidance Responsibility*: - The pilot, with autonomous capability of RPA - ATC has to be informed
	U-Space / UTM (Under definition)	- Urban/Non-urban areas & Very Low Level Flight (VLL) - E-Ident, Geofencing - High level of connectivity - High density of traffic (manned and unmanned), terrain, fixed obstacles (buildings, trees, etc), mobile obstacles (cranes), birds, cables, etc	

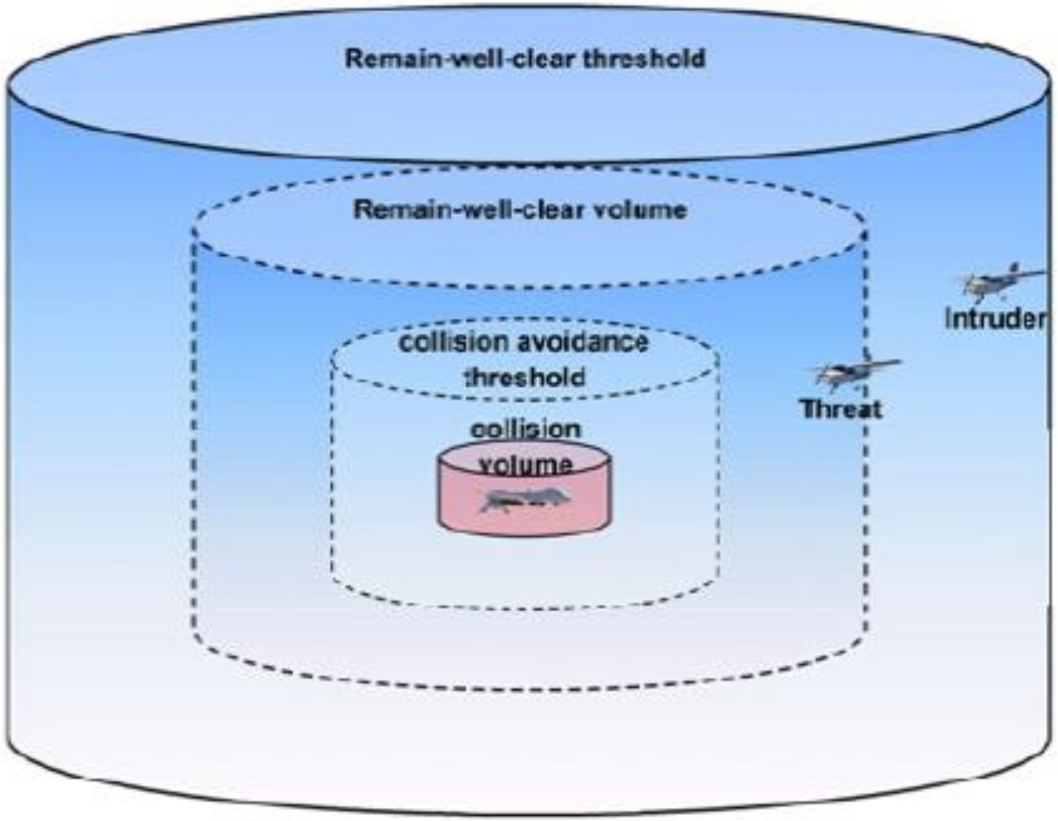


Sense & Avoid: Functional Analysis

- *Surveillance Functions: Traffic Detection*



Protection Layers



Geometry of RWC assurance and CA

Source: ICAO RPAS Manual Doc 10019AN/507 Ed.1, 2015

Sense & Avoid - Architecture Analysis

MANNED

SEE *(SURV)*
Sensors and/or Pilot Observation
Maneuver indication (TCAS, TAWS, Weather)

PILOT ACTIONS
Decision Making, Maneuver initiation for Separation and Collision Avoidance
ATC communication

AVOID *(FCS/FMS)*
A/C Maneuver execution

UNMANNED

DETECT *(SURV)*

- *Sensors:Traffic/Terrain/Obstacles/Weather*
  - *Detect & Tracking*
- *Data fusion & Correlation & Tracking*
- *RWC: Thresholds monitoring and Alerting*
  - *Suggestive maneuver indication*
- *CA: Thresholds monitoring and Alerting*
  - *Directive maneuver indication*
- *Situation awareness provided to the pilot*
- *CoC (Clear of Conflict) detection*

PILOT ACTIONS

- *Pilot Observation & ATC comms.*
- *Decision Making: RWC initiation, CA monitoring and/or flight command*

STANDARD INTERFACE

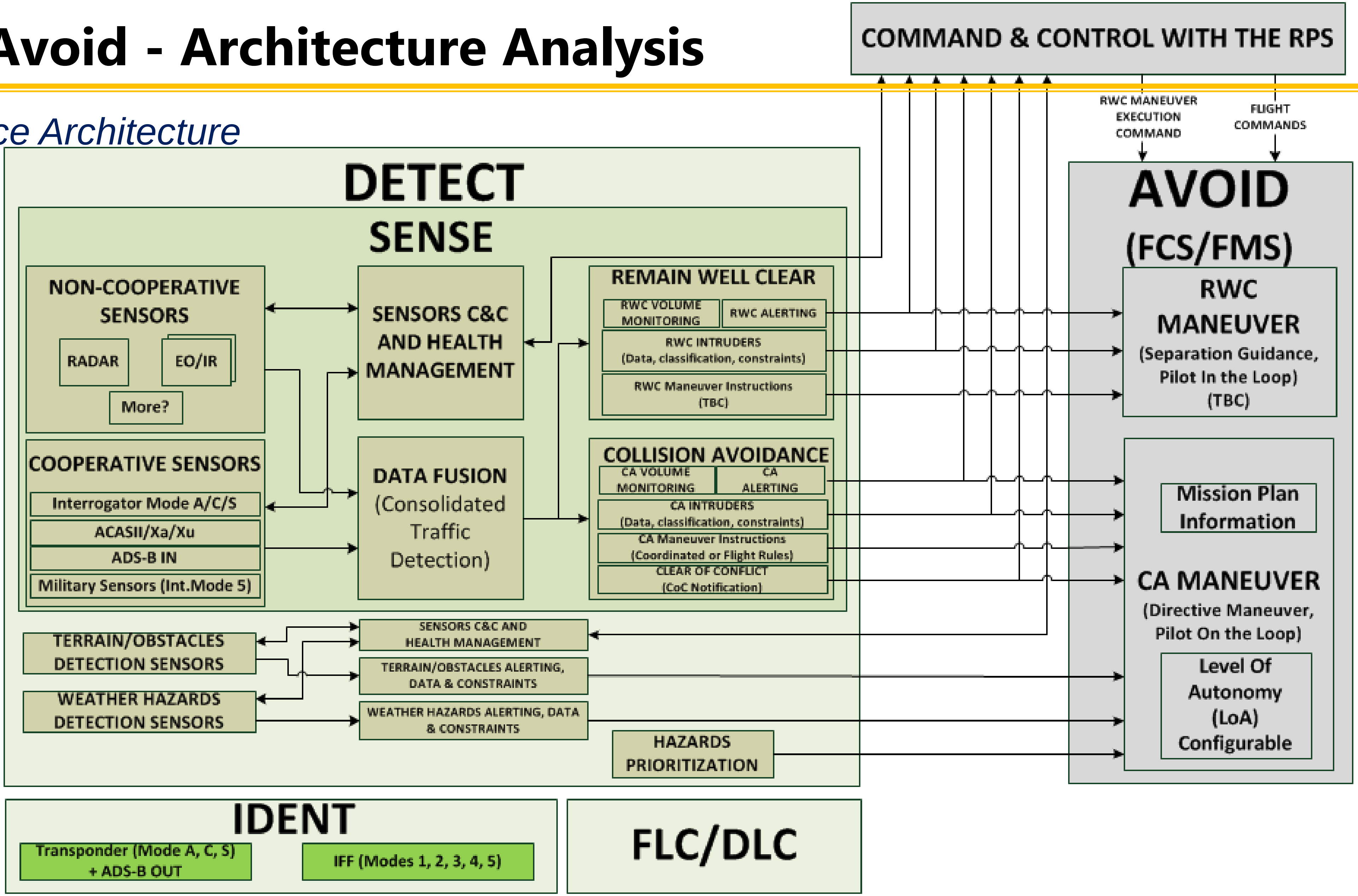
- *RWC maneuver indication*
- *CA maneuver indication (directive)*
- *Hazards data*
- *Alerting (& priorization)*
- *A/C Position & Status*

AVOID *(FCS/FMS)*

- *Keep flying in the same flight mode*
- *RWC maneuver generation: based on WPs?*
- *Execute RWC maneuver after pilot command (automatic mode?)*
- *Execute CA directive maneuver: based on CA maneuver indication, vertical / horizontal command (semi-automatic mode?)*
- *Execute any flight command from the pilot*
- *Return to the Flight Plan when CoC (after pilot command?)*

Sense & Avoid - Architecture Analysis

- *Surveillance Architecture*



Sense & Avoid - Architecture Analysis

- ***Main Characteristics of Detect & Avoid System:***
  - ***CIVIL** (Based on Civil Modes / Capabilities) **ON/OFF***
  - ***MILITARY** (Based on Military Modes / Capabilities) **ON/OFF***

  DETECT Reconfigurable, Open, Scalable, Modular

  - ***DETECT** more dependent on **Sensors** performance*
  - ***AVOID** more dependent on **Aircraft** performance, and independent of sensors*

  STANDARD INTERFACE DETECT-AVOID

  - ***HAZARDS PRIORITIZATION CONFIGURABLE.** Hazards Detection & Prioritization depend on Civil/Military env. and Certification of a specific RPAS.*
  - ***AVOID: LoA CONFIGURABLE for a multi-role RPAS.** CA Maneuver criteria and LoA could be different depending on Civil/Military env., Safety/Certif. considerations for a specific RPAS, etc → Mission Plan information is required*

- ***Safety Analysis shall be performed** for different scenarios (DL Loss, C&C Loss, DAA Sensors Degradation/Loss, RPA Health Status, DAA Loss, etc)*
- *Typically **TCAS II** equipment is DAL B (CS-25) due to "False RA in case of an actual threat" is classified as a **Hazardous** Failure Condition → SIMPLEX Architecture*
- *Typically a **Transponder with TCAS II interface** has a **Hazardous** FC due to the contribution to "False RA in case of an actual threat" → DAL B (CS-25) → SIMPLEX or DUPLEX*

- ***JARUS RPAS-AMC-1309 Iss2, Hazardous FC:***

	DETECT	AVOID
CS-LUAS	10^{-5} DALC (CL I), 10^{-6} DALB (CL II)	TBD
CS-23 Class I	10^{-5} DALC (CL I), 10^{-6} DALC (CL II)	TBD
CS-23 Class II	10^{-6} DALC (CL I), 10^{-7} DALB (CL II)	TBD
CS-23 Class III	10^{-7} DALC (CL I), 10^{-7} DALB (CL II)	TBD

Sense & Avoid - Market Survey

- ***Transponders**: Modes A/C/S & ADS-B Out*
  - *Suppliers under assessment: uAvionics, Dynon, Sagetech, etc*
- ***Transponders/IFFs**: Modes A/C/S & ADS-B Out & Modes 1/2/3/4/5*
  - *Hensoldt, THALES, Indra, Raytheon, Leonardo, etc*
- ***Cameras (FLC, DLC, EO/IR):***
  - *Kappa, Secureplane, SEKAI Electronics, etc*
- ***Weather & Terrain Sensors (WxR, TAWS, ...):***
  - *Suppliers under assessment*
- ***DETECT (Detect & Avoid):***

Equipment designed for UAVs
- Lighter
- Smaller
- ITAR Free (nice to have)
- Exportable (nice to have)
- DAL C / DAL B
- DO-160G
- DO-178B/C
- DO-254
- Interfaces

INTEGRATED SYSTEM

- ***Thales**: Development stage, under assessment*
- *Indra: No development, MIDCAS involvement.*
- *Hensoldt: No development, only Radar available, under assessment.*
- ***Honeywell**: Development stage, under assessment*
  (First version with TCAS II, 2021 / ACAS Xa/Xu 2024 (SESAR))
- *Telephonics, FreeFlightSystems: No development*
- ***NLR**: In progress.They have experience in different DAA techniques.(TRAWA)*
- *Flarm: In progress. They have some experience for small GA cooperative A/C.*
- *Rockwell Collins, Raytheon, Safran, IAI, Sagetech, Leonardo, etc pending to receive an answer.*

NO DAA MATURE/COTS PRODUCT**: suppliers involved in DAA are in a very early stage of development → **THERE ARE NOT STANDARDS

INDEPENDENT SYSTEMS

- *CIT Interrogator : Modes A/C/S & ADS-B Out & Modes 1/2/3/4/5*
- *TCAS: Pending to assess equipment for UAVs.*
- *ADS-B In Receiver : Pending to assess equipment for UAVs*
- *Radar, EO/IR, Lidar, Weather, Terrain sensors and Mode 5 Int. to be assessed.*
- ***Alternative: Develop an own Airbus DAA, based on these independent solutions.***

"DETECT" (Surv): MAKE/BUY DECISION

"AVOID" (FMS/FCS): MAKE, Airbus Development