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FACT

FUTURE ALL AVIATION CNS TECHNOLOGY

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Abstract

This document is follower to deliverable D4.1. For the defined categories of low and very low altitude airspace users, it describes their specifics for CNS equipment requirements, technical, business and operational. For the operational point of view, typical operations are described and requirements for in-flight services are set. Technical requirements are described using required transmission range, equipment weight, power source or suitable sensors. Business aspects focus mainly on predictions of market size and cost of development driven primarily by certification requirements.

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1 Introduction

1.1 Executive Summary

Currently, future air traffic is expected to grow both in the field of convivial aviation and new unmanned aerial vehicles. This will inevitably lead to higher collision risks and new requirements for traffic management and corresponding CNS equipment.

Currently the regulations for air traffic are governed by the rules for the ICAO defined airspace classes A through G. Various special regulations exist in addition within restricted areas of different types, whose limits are published regularly in national AIPs or ad hoc in NOTAMs. Pilots and flight planners are well informed and plan their flights as required by those rules. Traffic conflicts between AUs are resolved by either ATCOs or by pilots trying to see other aircraft and avoid a collision if sufficient visibility exists. Drones, either following autonomously a predefined flight path or are controlled by a drone pilot from the ground, however, are restricted to segregated airspaces, typically to remain below 100 m (~ 300 ft) AGL and to a defined distance to landing sites. Further limitations can be specified within the control software of a drone to stay automatically inside or outside a pre-defined block of airspace (geo-fencing).

This document builds on the deliverable D4.1 where typical parameters of airspace users were described. Operational challenges and business aspects are discussed and as results, specific CNS requirements for airspace users are established.

1.2 Acronyms

ACAS	Aircraft Collision Avoidance System
ADS-B	Automatic Dependent Surveillance-Broadcast
AGL	Above Ground Level
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATCo	Air Traffic Controller
ATM	Air Traffic Management
AU	Airspace User
BVLOS	Beyond Visual Line of Sight
C2	Command & Control
CIS	Common Information Sharing
CMU	Communications Management Unit

CNS	Communication, Navigation and Surveillance
COTS	Commercial Off-the-Shelf
CPDLC	Controller Pilot Data Link Communications
CSP	Communication Service Provider
CTR	Controlled Traffic Region
DAA	Detect And Avoid
DME	Distance Measuring Equipment
EASA	European Union Aviation Safety Agency
eID	Electronic Identification
ELT	Emergency Locator Transmitter. Automatically Transmits Emergency Messages to Satellite System in case of a crash.
eVTOL	Electric Vertical Take-Off and Landing
FAA	Federal Aviation Administration
FIS	Flight Information Service
FLARM	Flight Alarm (this acronym here always implies FlightAware/Rosetta) and similar uncertified proprietary products currently use for traffic avoidance)
GA/R	General Aviation/Rotorcraft
GNSS	Global Navigation Satellite System
HF	High Frequency
HTAWS	Helicopter Terrain Awareness and Warning System
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
ILS	Instrument Landing System
MOPS	Minimum Operational Performance Standard
MTOW	Maximum Take-off Weight
NAV	Navigation
NOTAM	Notice To Airmen
PBN	Performance Based Navigation

PIREP	Pilot Report
QNH	Mean Sea Level Pressure
RNP	Required Navigational Performance
SAR	Search And Rescue
SBAS	Space Based Augmentation System
SRD	Short Range Device
SSR	Secondary Surveillance Radar
SVFR	Special visual flight rules
SWaP	Size, Weight and Power Consumption
S&A	See and avoid, method of traffic separation under VFR
TAWS	Terrain Awareness and Warning System
TCAS	Traffic Alert and Collision Avoidance System
TIS-B	Traffic Information Service – Broadcast
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System
UAT	Universal Access Transceiver
UHF	Ultra High Frequency
USSP	U-Space Service Provider
UTM	Unmanned Traffic Management
V2V	Vehicle to Vehicle data transmission
VDL	VHF Data Link
VFR	Visual Flight Rules
VHF	Very High Frequency
VLOS	Visual Line of Sight
VoIP	Voice Over Internet Protocol
VOR	VHF omnidirectional range
WAAS	Wide Area Augmentation System

2 Overview of Airspace Users Operations

2.1 Airspace Users Operations within the Scope of FACT

Airspace Users **in scope** of the FACT project operate various types of aircraft shown section 3.2 below and technically described in the D4.1 Summary of the Current Business Situation.

Their operations are mapped onto their respective airspace class operations (A through G including U-Space), and actual operating modes, such as pilot training, check flights, air work, SAR operations, private or commercial air transport, pleasure or sightseeing flights, air shows, competitions and others. This mapping is provided in the Section 3.

The latter are assumed to have similar needs as aircraft flying on scheduled flights and operate in controlled airspaces only. Business Aircraft occasionally operating from/to uncontrolled airfields, however, are considered to be within the scope of FACT, because they have similar operational needs as light airplanes and operate in uncontrolled airspace.

Manned UAM traffic such as Air Taxis are expected for the next few years to follow current ICAO VFR rules This implies a minimum visibility 800 m, and free of clouds with visibility to the ground in uncontrolled airspace (Class G) (similar to helicopters) - and more up to 8000 m in controlled airspace (Classes C,D,E,…) with vertical/horizontal distances from clouds and flight visibility from 500ft/5 km up to 1000ft/8 km.. The airspeed in all cases is limited to less than 250 kn. Consequently their CNS equipment should at minimum similar to today’s light GA aircraft.

Traffic rules and CNS equipment for night flights and access to/from Vertiports still need to be established. IFR rules for such flights and unmanned flights may be possible some years later, depending on their respective certification and additional traffic rules.

Out of scope in this context will be the operation of

- Operational Traffic[1] including military drones, and
- (Commercial) Aircraft on scheduled flights, and high-end Business Aircraft which operate primarily under IFR and follow traditional ATC.

2.2 Aircraft Types and Operations

Airspace Users **in scope** of the FACT project are classified in the D4.1 deliverable with proper description of particular specifics. Following table provides visualisation of each category typical representative.

[1] The term Operational Air Traffic (OAT) is applied in Europe to all flights which do not comply with the provisions stated for general air traffic (GAT) and for which rules and procedures have been specified by appropriate national authorities. (EUROCONTROL EATM Glossary of Terms) Most OAT flights are operated by military agencies.

1 - Glider 	2 – Motorized Glider 	3 – Hang Glider 
4 –Small Rotorcraft 	5 – Large Rotorcraft 	6 – Large Rotorcraft 
7 – Para Glider 	8 – Hot Air Balloon 	9 – Gyrocopter 
10 – GA Aircraft –Beechcraft A65 	11 – GA Aircraft – Cessna 172F 	12 – GA Aircraft – Cirrus SR22 

Figure 1: Examples of Aircraft Types

AU Group Picture # in Fig. 1	Airspace Classes Flight Rules in use Day/Night Ops	Airfields / Take-off-/Landing Sites in use	COM / NAV Equipment for ATC (typical)	Transponders ADS-B in/out (typically Estimated share of equipped aircraft	Traffic Information / Avoidance
Light GA 10,11,12	All: A..G IFR+VFR, day+night if equipped	All, controlled or uncontrolled	2-way VHF radio, ILS, VOR, NDB, GNSS	Mode C or –S, ADS-B < 10 %; FLARM / PilotAware ~ 30 %	ATC/FIS or S&A, depending on flight conditions
Ultra-Light GA and motorised gliders 2,3,9	All: A..G IFR+VFR, day+night if equipped	All, controlled or uncontrolled	2-way VHF radio GNSS	Mode C or –S, ADS-B < 10 %; FLARM / PilotAwware ~ 50 %	Mostly S&A
Hang Glider 3	G, exceptions for long competitions (long distance or high altitude	Special sites for take-off and landing	Mobile Phone		always S&A
Glider 1	Classes E,G, other with ATC Clearances VFR exceptions for long competitions (long distance or high altitude	Uncontrolled take-off and landing, off-airfield landings legal	2-way VHF radio GNSS	FLARM / PilotAware regionally	FLARM / PilotAware regionally
Rotorcraft SAR / Police 4,5	All: A..G IFR+VFR, day+night if equipped	Off airfield landings normal	2-way VHF radio, ILS, VOR, NDB, GNSS	FLARM / PilotAware regionally to be visible for air sports	Mostly S&A
Rotorcraft Airwork 6	All classes A..G; VFR, day+night if equipped	Off airfield landings normal	2-way VHF radio, ILS, VOR, NDB, GNSS	Mode C or –S	Mostly S&A
Balloons 8	Classes C..G VFR day	Any suitable site of take-off and landing.	2-way VHF radio	Mode C or –S	n/a balloons always have right of way.
Parachutes / Para-Glider 7	All classes A..G; VFR, controlled airspace with clearance to aircraft		Mobile Phone to ground team	none	n/a

Table 1: Overview of current operations and typical equipment

The following table presents overview of emerging or awaited types of drones and their respective operation for business.

Example photo	**Typical Characteristics**
	**Fixed wing drone** - Propulsion: Electric / Benzine Weight 5.. 20 kp, max flight duration 30 min Flight path: ground controlled or autonomously (pre-planned) Take-off / Landing: A flat area without obstructions close to the flight path required.
	**Multicopter drone** Weight 5.. 20 kp, max flight duration 20 min Flight path: ground controlled or autonomously (pre-planned) Take-off / Landing: vertical takeoff/landing possible.
	**Air Taxi**, prototype in flight tests. *Lilium Jet*: max 7 persons, initially with pilot, later autonomous. Altitudes 0 - 10.000 ft, TAS ~ 120 knots,, range ~ 250 km. Business Model: Replacement for local flights between adjacent commercial airports and to/from city centres to airports. Weight ~ 1,7 t. Initially with pilot, planned for autonomous operations.
	**Air Taxi,** prototype in flight tests and limited demo operation, max 4 persons, weight ~ 1,2 t, with pilot, planned for autonomous operations. *Volocopter:* (similar operational characteristics as above)
	**Light Drone:** Transport of light equipment, e.g. cameras, or urgent light deliveries such as medical equipment, parcels or biological samples. Weight 5 - 15 kp.
	**Heavy Drone:** Cost effective replacement for former traditional Helicopter business, e.g. inspection for pipelines, electric power lines, Search and Rescue support during disasters and other emergencies. Weight < 150 kp, endurance < 2 hrs

Table 2: Examples of Drones and Air Taxis

3 Operational Challenges

3.1 Existing Challenges

This section summarizes known problems in aviation today which are expected to become more relevant soon.

Regulation:
See and Avoid is still a well proven practice in airspace classes E and G. However, with higher volumes of traffic, additional technical means should be needed, especially close to airfields or in very low altitudes above cities. Current status of fragmented and unreliable traffic information leads to inflexible airspace allocation and to inflexible segregation.

Technology:
ADS-B Out based on **ES1090** as mandated today in Europe is not feasible for the highest traffic volumes in low airspace as data transmission will become saturated and data will be lost. In North America (Canada and USA) therefore an alternate channel for data transmission based on **UAT** is implemented since 2020. Many aircraft in Europe are equipped with either **FLARM** in Central Europe or **PilotAware**[2] products - mainly in UK - products on a voluntary basis, however, an area wide comprehensive ground service which links ADS-B and those services to create the full picture is not in sight.

Economy:
Availability, quality level and cost of U-Space services for different types of users are still not completely clear. Furthermore, there is a lot of uncertainty concerning speed of practical deployment and coverage of the services as well as how the transition period will be managed.

Safety:
The fact that many airspace users (mainly from the air sports domain) are not aware of those risks and there consequently is little engagement by their associations, contributes. Moreover, there is neither a consistent event reporting system in place, and obviously statistic data is not available.

3.2 Upcoming Challenges

All issues listed in previous section will become even more relevant and need a solution with the increase of drone traffic. Reliable traffic information and conflict resolution by minimizing the application of segregated airspaces will be mandatory. Issues to be resolved are:

Safety / Regulations
Many airspace users depend on ad-hoc off-airfield operations: Gilders, SAR, Airwork, any airplane in distress or to avoid severe weather. There is a need to set up clear rules with defined priorities. For example, drone operators must be aware of these situations.

[2] Details at https://de.pilotaware.com/rosetta

New technological features will need to define target performance parameters. Required performance will differ between airspace users and it will be given by safety analysis.

Per [For UAMs aiming to perform fully autonomous flights would require modification of current regulations, or new regulations altogether, including:

- Beyond visual line of sight (BVLOS) (waiver to 14 CFR Part 107.31)
- Operations over people, streets, etc. (waiver to 14 CFR Part 107.39)
- Carrying air cargo commercially and across state lines (addressed in Section 348 of the new FAA Reauthorization Act of 2018)
- Airworthiness for carrying a passenger or patient (14 CFR Part 23)
- Flights in instrument meteorological conditions
- Airworthiness certification of autonomous and remotely piloted aircraft
- Training and knowledge requirements for pilots and operators (addressed in Section 349 of the new FAA Reauthorization Act of 2018)

Technology:
From the technology point of view, reliable reporting of own position is key for future safe traffic. Different candidate technologies are considered. New EASA regulation (update of Acceptable Means of Compliance) requires that each aircraft operating in U-space reports its position through one of the three technologies: ADS-B Out (1090MHz), SRD 860Mhz, or cellular network.

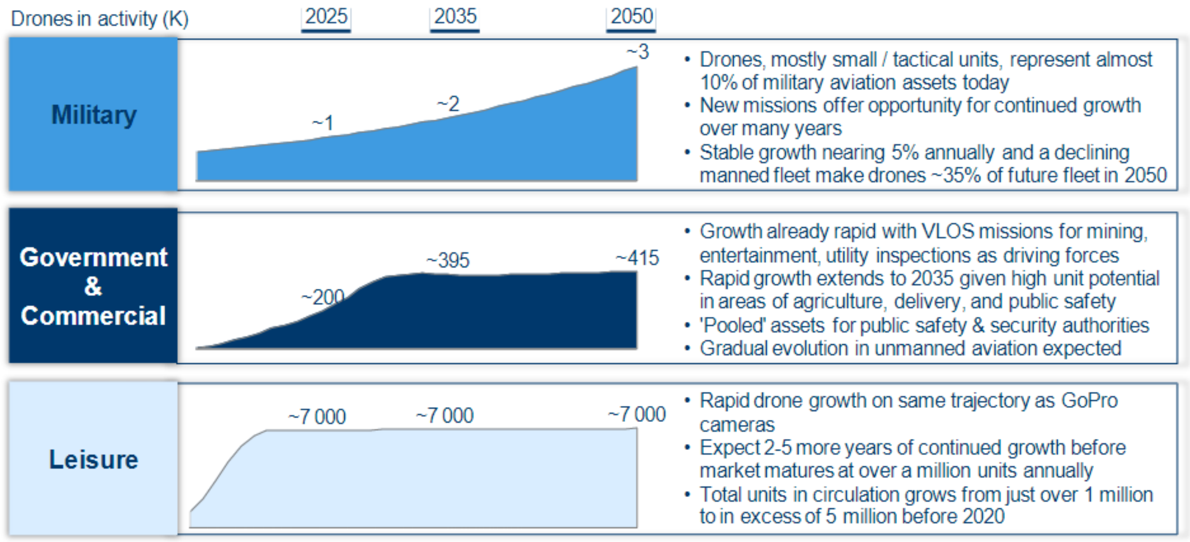
Next, direct communication (vehicle to vehicle) between lower classes of vehicles will be highly beneficial. This feature is next technology challenge to overcome.

Economy:
When considering use of cellular networks, there is a key question if this kind of business will be enough interesting for telecommunication companies. There are possibilities like operating network slice by traffic operator which may be reasonable.

Safety:
Safety risks are caused by increased traffic volume and sometimes limited risk assessment of light drone operators. In case of a collision they risk the loss of their equipment, while GA pilots risk equipment, injury or even life. While new EASA regulation framework significantly improves the situation, the formation of the whole new eco-system will yet need some time.

4 Business Forecasts

The main business challenge is related to market predictions and estimates of the speed with which the new air traffic controllers will push. For illustration, the European Drones Outlook Study [9] provides some forecasts of drones in activity.



[8] Number of military drones based on EDA database provided February 2016
[9] Number of traditional military aircraft sourced from SESAR ATM Master Plan forecast
[10] Leisure based on global sales and average prices; Europe estimated at 30% of units

Figure 2: Prediction of Drone Fleet Size from Current to 2050

European Drone Outlook study brings another interesting comparison – number of drones and manned aircraft (excluding general aviation):

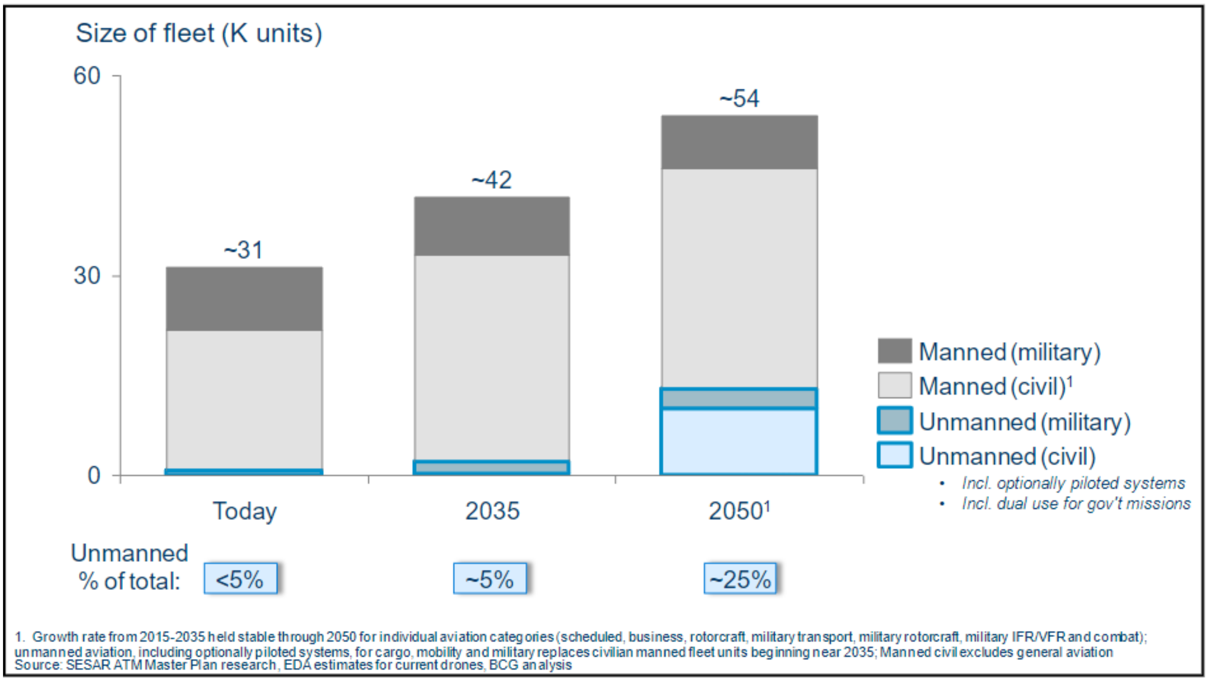


Figure 3: Comparison of defence and certified drones vs. manned aircraft (excluding general aviation)

To summarize the plot, there is a forecast that unmanned systems can represent about 25 % of all aircraft by 2050 (GA aircraft and hobby drones primarily for very low altitudes excluded).

Regarding the Urban air Mobility, per [11] eVTOLs may have a viable market in 2025 with around 4,000 vehicles in operation and 23,000 vehicles in 2030. Reports and Data [12] estimate that in the USA is a potential demand for 55,000 daily eVTOL trips.

5 CNS Services and Solutions

This section provides an overview on CNS **equipment** currently in use per AU group and describes potential solutions in a future CNS environment which includes additional **services** based on cellular mobile communication. Considering the large variations within a AU group, depending on the age of the aircraft in use, its typical operation (from occasional VFR sightseeing flights to full commercial IFR flights at all weather conditions, to acrobatics and flight tests, flight training, air work, pilot's check flights,...) it is impossible to discuss all possible variations here. The following paragraphs describe the typical cases considered in scope of FACT, e.g. military flights and commercial airline flights are out of scope, however, certain regional commercial flights to uncontrolled aerodromes need to be considered.

Currently flight rules and airspaces to be used for traditional air traffic and drone traffic are incompatible, which had led to the application of segregated airspaces with incompatible traffic rules for traditional AUs and UAM-aircraft and drones in different states. This is a disadvantage for both sides. Traditional AUs have the need to fly into the very low airspace (typical < 500 ft AGL) used by drones for emergencies, take-offs and landings at private and/or uncontrolled airfields or at any reasonable off-airfield place (e.g. gliders). Drones, however, are forced to fly long deviations around protected airspaces, e.g. busy airports with CTRs, but also any other aerodrome, such as heliports (e.g. at hospitals) to avoid traffic conflicts. Such deviations limit their effective range considerably, which is a disadvantage for their business. Moreover, there are business cases for drones to fly from/to controlled airports, which requires appropriate services by ATC. Visual separation between drones and traditional AU flights is nearly impossible at daylight due to the small size of most drones, and completely impossible at night. Therefore, the drone operator or an USSP on the ground needs to maintain a reliable traffic picture within a reasonable distance to his drone(s).

What we described above is only a small part of all possible traffic situations which will occur in airspaces where drones and traditional AUs might come into conflict. All situations have in common that a reliable data link for the surveillance applications of the current traffic situation and intents, allowing to display graphically and/or as text to all parties concerned is mandatory. In addition, for any non-standard situation, a voice link could be very helpful.

A very promising approach is the use of cellular networks. Even limited flight demonstrations within FACT show, how reliable data exchange is important for mixed traffic situations and indicate its feasibility. The main advantages are:

- The hardware, airborne and on the ground, follows international industry standard and is relatively cheap compared to any analogue VHF voice communication equipment. No new frequency band in the VHF/UHF aviation bands is required (at least for Solution 1 addressing use of public networks).
- Airborne systems have low physical weight and low electrical power consumption, which is important not only for drones, but also for gliders and other air sports aircraft which depend on rechargeable accumulators. Existing airborne displays systems typically have wireless interfaces (WiFi or Bluetooth) to display the actual traffic situation, therefore no additional internal cable connections are needed, only simple software configuration is sufficient. If integrated displays are not installed, a tablet computer would be sufficient. For voice

communication through that network only one free channel in the aircraft's audio panel is required.

- Ground systems for ATC, USSP and ground drone pilots are usually provided with Internet connection. For security reasons separate backup power should be available. Application software still needs to be specified, but many building blocks already exist.

- Independently, the airborne equipment should be capable of standardized and interoperable (in progress and still evolving discussion) V2V traffic data exchange. This should always be an option for flights outside of the reception area of a ground station, very similar to ADS-B in+out and FLARM in+out today. It would provide not only a 2nd level of safety of flights outside the reception area of ground stations, e.g. in mountainous regions, but offers an assistance also during part time service of the USSP or outage of ground stations form other reasons. Last not least, most drone business is initially expected for high density traffic areas, typically near large cities. But with V2V traffic data exceptional excursions by a drone to a remote area would become much safer.

An overview of the currently available CNS equipment per relevant AU groups is provided in Table 1. In the paragraphs below we describe emerging CNS needs of AU groups for future operations. Current mandatory and typical equipment is described in the D4.1 Summary of the Current Business Operation.

5.1 Manned Free Balloons

CNS Operational surveillance needs

Balloons have limited control of their altitude, their flight path depends on the actual wind. They have a right of way against all other AUs. Consequently, they have to be seen and avoided by all others.

Expected CNS capabilities & services needed in future

GNSS and barometric sensor for automatic position reporting when moving in U-Space. Candidate technologies are ADS-B, FLARM or cellular network. This is applicable also for unmanned balloons, e.g. weather balloons.

5.2 Light GA Aircraft (CS-23)

CNS Operational surveillance needs

Voice communication with ATC, being seen by other traffic. Separation from surrounding traffic in uncontrolled airspace (See and Avoid used today).

Expected CNS capabilities & services needed in future

There is expectation of GNSS becoming mandatory. A cellular network router which transmits own position data and receives traffic data within a defined distance (e.g. 5 NM) or via V2V. Potentially transition to VoIP communication with ANSP. If a capable autopilot is in use, in addition to position data, flight intentions may be transmitted as well. Automatic FIS: i.e. overall and local weather situation, ATIS, airspace/airport restrictions should become available from both: ANSP and USSP. Some kind of ACAS/DAA or at least situation awareness application supporting pilot's separation tasks in uncontrolled airspace especially considering new types of users.

5.3 Ultralight Aircraft (CS-23 VLA)

Operational surveillance needs

Voice communication with ATC, being seen by other traffic. Separation from surrounding traffic in uncontrolled airspace (See and Avoid used today).

Expected CNS capabilities & services needed in future

Similar to section 5.2. CNS solution for ultralight a/c needs to be really lightweight.

5.4 Glider – Sailplanes

CNS Operational surveillance needs

Voice communication with ATC, being seen by other traffic. Collision avoidance from surrounding traffic in uncontrolled airspace (See and Avoid and FLARM (when available) used today).

Expected CNS capabilities & services needed in future

A cellular network router which transmits own position data and receives traffic data within a defined distance (e.g. 5 NM) or via V2V. Potentially transition to VoIP communication with ANSP.

Automatic FIS: would help on long distance flights through special smartphone apps using public cellular network or to interface with the U-space services.

5.5 Glider - Paragliders

Operational surveillance needs

Being seen and strictly see and avoid in uncontrolled airspace.

CNS capabilities & services needed in future

GNSS with barometric sensor and mobile phone for correct and mandatory position reporting to other AUs in U-space. In addition, V2V position reports outside U-Space in mountainous areas could help to prevent conflicts with gliders and GA aircraft, considering that they are able to fly high above mountain tops in up-wind situations.

5.6 Small Helicopters (CS-27)

Operational surveillance needs

Voice communication with ATC, being seen by other traffic. Separation from surrounding traffic in uncontrolled airspace (See and Avoid used today).

Expected CNS capabilities & services needed in future

A cellular network router which transmits own position data and receives traffic data within a defined distance (e.g. 5 NM) or via V2V. Potentially transition to VoIP communication with ANSP. If a capable autopilot is in use, in addition to position data, flight intentions may be transmitted as well. Automatic

FIS: i.e. overall and local weather situation, ATIS, airspace/airport restrictions should become available through both: ANSP and USSP.

5.7 Large Helicopter (CS-29)

CNS Operational surveillance needs

Voice communication with ATC, being seen by other traffic. Separation from surrounding traffic in uncontrolled airspace (See and Avoid used today). Collision avoidance capability – for large part of these vehicles it is mandatory. Terrain awareness systems such as HTAWS.

Expected CNS capabilities & services needed in future

As off-airfield take-off and landings belong to the standard operations of this group of AUs, a cellular network router which receives traffic data within a defined distance (e.g. 5 NM) or via V2V. Potentially transition to VoIP communication with ATC. In addition, TCAS II is not designed for helicopters so it's use is not ideal in terms of efficiency. It should be replaced by ACAS Xr variant for rotorcraft which is currently under development and beyond collision avoidance should provide also support to remain well clear (separation) task.

5.8 GA CS-23 Class III Aircraft

Operational surveillance needs

Voice communication with ATC, being seen by other traffic. Separation from surrounding traffic in uncontrolled airspace (See and Avoid used today). Collision avoidance capability – for large part of these vehicles it is mandatory.

Expected CNS capabilities & services needed in future

On a case-by-case basis a cellular network router which receives traffic data about surrounding traffic within a defined distance (e.g. 5 NM) and potentially transition to VoIP communication with ATC.

5.9 Drones

Operational surveillance needs

Operational requirements varies according the type of operations and whether they are performed as Line-Of-Sight (LOS), Visual LOS (VLOS) or Beyond Visual Line of Sight (BVLOS). The CNS requirements are driven by mitigation means identified using SORA risk assessment for given operations and environment. Nevertheless, the basic common requirement is to be seen and corresponding eID capability is required in U-space from 2023 by EASA regulation. Based on the SORA various types of DAA capabilities may be needed, however, today's operations are performed always in segregated airspace which reduce the need of DAA but represents serious operational limitations.

CNS capabilities & services in use today

In most cases, the only way how the drone operator reports vehicle positions is from its ground control station (which receives this information through proprietary C2 link) using some of the conventional ground internet connection. EASA regulation requires eID position reporting through one of the three ways: ADS-B Out, SRD 860 (frequency band used also by FLARM), or cellular network. However, only for ADS-B there are existing technical standards/specifications.

Commercial drones operations are typically performed through automatic way, so the planned trajectory (3D) is available and can be in principle shared as well. Nevertheless, there are not standardized specifications/protocols for such sharing yet.

Expected CNS capabilities & services needed in future

Position reporting via electronic ID is part of U-Space requirements, cellular network being one of the three proposed candidates. However, EASA regulation currently address only how to get position information to the ground and do not specify implementation of TIS which is key to provide resulting traffic picture to individual AUs. Public network could be used for this purpose especially for low altitude operations.

For collision avoidance, there is an ACAS Xu system designed for larger drones. RTCA has published the DO-386 in December 2020. Corresponding EUROCAE document is ED-275, published also in 2020. Significant benefit of the ACAS Xu is that it provides in addition to the collision avoidance also the remain well clear functionality and is designed to work with air-to-air radar. Also it takes into account flight characteristics of RPAS and uses both horizontal and vertical (as well as blended) maneuvers

ACAS sXu is another variant of ACAS X intended for smaller drones. Its development is concluding with new MOPS standard by end of 2022. It provides only collision avoidance functionality, and it is designed to support operations in very low altitudes (it includes tools to handle ground obstacles at the same time as traffic). However, this standard development was not adopted so far by EUROCAE, so the European version of the standard is not expected soon.

Key gap on the market is availability of suitable non-cooperative sensor as it is an indispensable part of onboard DAA for these vehicles. The main advantage in non-cooperative sensing technology is that aircraft that intended to receive the information do not need to be equipped with the same sensing technology. These sensors can be also able to detect ground obstacles and terrain. Non-cooperative technologies are primarily classified into two categories; they are active and passive sensors. Active sensors detect when the signal emitted from it has been reflected back towards it from the obstacle. Examples of active sensors are Radar, Sonar and LIDAR. Passive sensors depend on the signal emitted by the obstacle for detection. Examples of passive sensors are Electro-Optic sensors, Acoustic and Infrared sensors. Basic overview of advantages and disadvantages of each sensor type is provided in Table 3. Although many of these technologies are actively developed, so far non-cooperative sensors on the market really meet operational needs of mixed traffic operations.

Main uncertainty in CNS requirements for drones is driven by unmature conflict management concept: whether considering splitting of functions/responsibility between airborne systems (e.g., onboard DAA) and ground systems (ground control station) and services (such as U-space tactical conflict management service), or balancing performance/safety objectives between strategic (for instance trajectory based) and tactical (separation management) parts of overall conflict management[3].

In addition, it is expected that demand for new services will come together with further evolution of U-space concept. Beyond, traditional services as traffic and weather information can further evolve as for instance real-time data collected from greater number of airspace users can be very beneficial to increase information density and quality.

Sensor name	Type	Detection Range	Application	Remarks
TCAS	Co-operative sensor	160 Km	Range and relative altitude	Suitable only for larger UAVs and detects only other crafts.
ADS-B	Co-operative sensor	240 Km	Relative position and relative velocity	Suitable for larger and medium UAVs, but it won't detect ground obstacles
RADAR	Non co-operative active sensor	35 Km	Relative position and velocity	Suitable for all types of UAVs
Laser	Non Co-operative active sensor	15 Km	Range , azimuth and elevation	Suitable for all types of UAVs
Electro-optic sensor	Non Co-operative passive sensor	20 Km	Azimuth and elevation	Widely used in smaller UAVs due to its small size and less weight
Acoustic	Non Co-operative passive sensor	10 Km	Range	Less popular when compared to others

Table 3: Overview of different sensors [6]

[3] Assuming for the moment that collision avoidance will play role of a safety net, and therefore is not included in overall ATM/UTM safety objectives. If this assumption won't be valid it will need to be considered jointly with the above two parts of conflict management.

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5.10 Urban Air Mobility

Operational surveillance needs

Initially, the piloted eVTOL operations will operate in a similar way as CS-23 aircraft (see Section 5.2) with gradual evolution towards the way of operating of larger unmanned vehicles. Therefore, operational needs will include voice communication with ATC (to be able operate under ATC control in controlled airspace) and being seen by other traffic ads well as ground service providers (ATC and USSP). Separation from surrounding traffic in uncontrolled airspace will probably starts with See and Avoid but as UAM vehicles will operate in U-space and can interfere more often with drones, the needs for DAA and compatibility with U-space tactical conflict management need to be considered from the start as evolution path.

There are not currently any UAM vehicle certified and in commercial service, however, based on the above description, similar requirements as for CS-23 aircraft are initially expected.

Expected CNS capabilities & services needed in future

Operation above urban environment in low altitudes means more strict requirements to navigation. On the other hand, communication requirements can benefit from availability of cellular networks. The situation is similar to CS-23 GA aircraft – quality of service needs to be solved.

Short distance of UAM vehicles to obstacles means challenges in signal propagation [11]. Combination of multiple links can represent way forward.

UAM operations are planned as autonomous over a longer time horizon which places requirement for full detect and avoid system. On-board sensing can be supported by ground traffic information, but non-cooperative sensor will be required. New version of ACAS X – ACAS Xr – is currently under development to support these types of vehicles/operations considering both cooperative (including data from ground or direct V2V link) and non-cooperative surveillance.

Traffic management services will be required for UAM vehicles. It can be expected that a number of new or expanded ground services will be needed for this type of user. Enhanced positioning augmented by ground systems or traffic information consolidated from data reported by other airspace users can act as an example.

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Figure 4: Various UAM aircraft types

6 Other Stakeholders

6.1 Airport Operators, ATC, U-Space Operators

From the perspective of air traffic controllers and airport operators, business factors to be considered in operations include safety, efficiency, and cost. Air traffic controllers and airport operators must ensure the safety of all aircraft in the air and on the ground, and must also strive for efficiency in operations to minimize delays and maximize cost savings. The cost of operations must also be managed, including both direct costs such as labor and fuel, and indirect costs such as time and resources. All of these factors must be taken into consideration when making operational decisions. With the projected increase in civil aviation and the introduction of heavy drone operations into the aviation ecosystem makes it necessary to have a well-designed and managed, and cost-effective communication system. Moreover, such a communication system must also consider the regulations, policies, and procedures to comply with the standards of the aviation industry.

6.2 Communication Service Providers (CSP)

Based on the project's outcomes, dedicated 4G/5G network is considered as the only option how could cellular network technology potentially meet requirements of safety critical ATM applications. Building of dedicated network would allow to address the availability at higher altitudes as well as guaranteed quality of service. Furthermore, the potential use of protected spectrum would provide additional possibilities to handle security aspects. Nevertheless, the deployment of such kind of network would require a considerably initial investment into a dedicated infrastructure and therefore sufficiently strong business case is a key enabler of such solution.

The key points which need to be agreed/clarified in the context of possible deployment of such dedicated network by a CSP are:

- Spectrum - who is the owner, what spectrum can be used in different countries, will there be any global/European approach?
- Owner of the ground network infrastructure, associated business case and regulatory requirements.

7 Conclusions

7.1 CNS for Mixed Air Traffic Operations

This document summarizes both existing and upcoming operational and business aspects of CNS equipment for low and very low altitude users. For each airspace user it discusses high-level requirements to CNS equipment for operations in heterogeneous environment.

This analysis serves to determine potential project results impact on business concept, addressed in the D4.3. From the analysis provided in this document it is obvious that CNS solution(s) addressing needs of mixed traffic low altitude operation should reflect following basic requirements:

- Affordable price
- Interoperability between GA/R, drones and UAM
- Low weight and power consumption of device
- Scalability and Modularity – one size does not fit to all – need to satisfy broad spectrum of customers
- Preserving of safety standard level corresponding to big aviation

7.2 Possible Reuse of Existing Infrastructure

The communication service provider needs to identify the best possible infrastructure to provide communication for the flying vehicles over a cellular network.

The flight trials in Turkey by FACT have demonstrated the technical capabilities of a public network to provide best effort connectivity for such kind of use cases. There are some advantages and disadvantages using public networks. 4G/5G networks are deployed nationwide with a very good basic connectivity. But several topics need to be discussed. Public networks are not optimized for the coverage in the air. Most likely the operator will have some concerns regarding the interference which will be increased by serving flying vehicles on top the terrestrial user. Also due to the optimization for the ground-based user the operator will only provide best effort services. A potential improvement could be the usage of devices (inside the flying vehicles) which can connect to more than one network (different operator, different technology) to reduce coverage holes. If the solution needs to work in more than one country the devices anyhow need to connect to different frequencies and different operators.

The better technical solution would be to deploy a private (dedicated) network which can serve also mission critical applications to guarantee the required performance (throughput. Latency, reliability,…). Beside the investment in the network infrastructure the available spectrum is the most important challenge. The best approach is to reserve an available spectrum for all countries which want to provide this service. A potential support could come from governments and regulator which could also improve the business case for the service provider.

Current deployments will not provide significant performance differences between 4G and 5G networks. In future the upcoming features of the 5G networks will improve the connectivity between the ground and flying vehicles (part of the requirements for the standardization). More features will develop and provide more flexibility. Therefore, in greenfield (private network) cases the 5G technology will be the future proof choice.

Mandatory airborne equipment based on mobile communications would offer the following benefits:

- **Technical:** Low weight (acceptable also for (para-)gliders, balloons, drones of nearly all sizes,..), small in size, low electric power consumption, industry standard internal data links (Bluetooth, WLAN).
- **Commercial:** low price due to existing mass production for aircraft equipment, ground stations, and many other mobile applications.
- **Operational:** Simple low-cost equipment for ground services: ATC and U-Space Services. Gradual implementation possible: From densely populated areas with high air traffic volumes and complex airspace/ U-space configurations using private 5G networks to regions with less traffic supported by a 4G public mobile network followed by remote locations without ground support and self-organised traffic.

7.3 V2V Direct Data Communications

While in commercial aviation direct exchange of traffic information (via ADS-B in/out) is a mandatory standard since many years, a comparable technical solution for the “low level” UAs exists only in the form of proprietary and uncertified equipment such as FLARM. Even though this is not mandatory there is a 90 % equipage rate within central Europe’s glider community. Moreover, there is an approximate 50% equipage rate within the single engine aircraft flying community operating mostly VFR because of their obvious value for safety of all AUs. Even helicopters of police and SAR (c.f. section 5.4) use it for the same reason for their frequent off-airfield operations. Nevertheless, the use of such proprietary solution inevitably causes serious interoperability issues. In this context, the discussion about a standardized V2V links is ongoing in multiple levels, in particular in the context of ACAS X development (RTCA SC-147 and EUROCAE WG-75).

Such standardized V2V link could be complementary to cellular network equipment enabling interaction with ground services.

7.4 Cellular network as a possible solution of interoperability issues

While the solution based on TIS service over cellular network may have lower performance than direct V2V link, it can still represent a meaningful and affordable solution until the standardization of new V2V link covering needs of new airspace users and GA/rotorcrafts is closed, and at the same time as an important complementary service helping with interoperability aspects. While different vehicles can report their position through different technologies (current EASA regulation for U-space allow ADS-B Out, SRD 860 (frequency band used by FLARM), or cellular network), all this information can be collected by ground systems and the complete traffic picture can be shared with all users through TIS to complement their on-board detection). In this context, it is worth to mention that new ACAS Xr system developed for pilots of rotorcrafts and UAM vehicles already considers both possibilities of receiving traffic information from ground service and via direct V2V link (on top of conventional cooperative surveillance using ADS-B or active interrogation, and potentially non-cooperative sensors). As a simpler alternative, traffic situation awareness systems supporting these new surveillance means can be developed in parallel.

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