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FACT

FUTURE ALL AVIATION CNS TECHNOLOGY

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Abstract

This document presents the classification of users of low and very low altitude airspace. It includes manned and unmanned vehicles, not forgetting gliders, balloons, or paragliders. For each type of user, it describes the typical representative of this category, its basic parameters and typical avionic equipment. In section five, the document then categorises the environment with emphasize on the potential interactions of each user.

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1 Introduction

Low altitude airspace is becoming more and more important theme with expected expansion of drones and new aircraft like air taxi (either manned or unmanned) known under term Urban Air Mobility. Activities exist to precisely define rules of movements in low heights, but they are not definitively established. NASA is defining own concept called NASA UTM (see more at [5]). There is similar activity in Europe under SESAR program – CORUS and CORUSXUAM (Concept of Operations for European UTM Systems - details can be found at [6]) and through new U-space regulatory framework of EASA.

Thus, it is a fact that there will be a rising amount of airspace users which are different from already existing and with specific technology needs. Spectrum of users is in range of conventional general aviation and rotorcraft through recreational airspace users as sailplanes or paragliders to emerging RPAS market. These potential customers differ from "big aerospace" in the emphasis to cost, lightweight and easy installation and maintenance requirements. This document is focused into differentiation of low altitude users and their typical avionics equipment.

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1.1 Acronyms and Definitions

ADS-B	Automatic Dependent Surveillance-Broadcast
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
CNS	Communication, Navigation and Surveillance
COTS	Commercial Off-the-Shelf
EASA	European Union Aviation Safety Agency
eID	Electronic Identification
FAA	Federal Aviation Administration
FIS	Flight Information Service
FLARM	Flight Alarm
FMS	Flight Management System
GA	General Aviation
GNSS	Global Navigation Satellite System
ICAO	International Civil Aviation Organisation
MTOW	Maximum Take-off Weight
NAV	Navigation
PBN	Performance Based Navigation
QNH	Mean Sea Level Pressure
SORA	Specific Operational Risk Assessment
SSR	Secondary Surveillance Radar
SWaP	Size, Weight and Power Consumption
TIS-B	Traffic Information Service – Broadcast
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System

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USSP	U-Space Service Provider
VFR	Visual Flight Rules
VHF	Very High Frequency

Table 1 – Acronyms and Definitions

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2 Low Altitude Airspace Users and Environment Typology

2.1 Low Altitude Airspace Definition

Term low altitude airspace is defined for the project purpose as covering the operations up to 4000 ft of altitude. This altitude limit is expected to cover also future UAM operations.

2.2 General Aviation Classification

General Aviation (GA) is term covering all civil aircrafts other than commercial airlines and military. It includes:

- private flying, flight training, air ambulance, police aviation, firefighting, air charter, gliding, skydiving
- homebuilt, light-sport and very light jets have emerged as new trends

GA aircraft are classified by EASA Certification Specification into CS-23 and CS-25 where:

- CS-23 (Normal, Utility, Aerobatic and Commuter Aeroplanes) classifies mostly single propeller, light twin propellers and some turboprop aircraft
- CS-25 (Large Aeroplanes) applies to commercial aircraft, mostly airliners and newer business jets

Time & effort required to design, built, test and certify a CS-25 aircraft (carries general public) is more extensive and expensive than for a CS-23 (higher safety levels). Aircraft below CS-23 category are evaluated differently in the Europe and in the USA. European aircraft are divided into Ultralight and Very Light category whereas US authorities define category Light Sport Aircraft as can be seen below. Rotorcraft are divided per weight into Normal and Transport category.

Presented aircraft typology is based mainly on regulatory distribution. The first intuitive division is on aircraft lighter than air and aircraft heavier than air. Then aircraft are categorized per its airworthiness category. These categories are quite similar in USA and Europe with small differences presented in Table 1. USA uses Title 14, Code of Regulation and its parts. European authorities use Certification Specifications (CS) regulations.

- Lighter-than-air
  - Non-steerable balloons, steerable airships
  - CS-31 – Manned Free Balloons
- Heavier-than-air
  - No engine

    - CS-22 Sailplanes and Powered Sailplanes
- Engine
    - Ultralight (< 450 kg Europe, <600 kg USA Light-sport aircraft)
    - Very Light Aircraft (Europe < 750 kg)
    - GA CS-23 – Normal Category Airplanes
        - Normal, Utility, Acrobatic MTOW < 5760 kg
        - Commuter MTOW < 8620 kg
            - ✓ Piston Engine - Single × Multi
            - ✓ Turboprop - Single × Multi
            - ✓ Turbine
    - GA CS-27 – Small Rotorcraft
    - GA CS-29 – Large Rotorcraft

2.3 Equipment Requirements in the USA and Europe

Equipment requirements differ according to aircraft Maximum Take-Off Weight (MTOW), airspace class and type of flight. In the USA, for VFR flight an airspeed indicator, altimeter, magnetic direction indicator and tachometer for each engine are required. If flight is performed in flight level above FL 240, the DME and suitable RNAV system is required. Instrument flight rules require two-way radio, attitude indicator with slip-skid and rate of turn, baro altimeter, clock and directional gyro indicator.

As for collision avoidance, TCAS II must be installed in all turbine engine aircraft with MTOW above 5 700 kg or capacity higher than 19 people. From Air Traffic Management point of view, Mode C Transponder is required in Class A, B and C airspace. Starting January 2020, ADS-B Out becomes mandatory in Class A, B, C and E airspace. This is just brief overview not considering possible exceptions. Please see 14 CFR 91.205 for complete rules.

European rules for aircraft equipment differ from state to state. Requirements related to Air Traffic Management are defined in the Aeronautical Information Publication for every country. Generally, requirements are very similar, but minor differences exist. For example, Czech AIP defines need for VHF radio with channel separation of 8.33 kHz, Mode A/C Transponder for all flights in Class C airspace and Mode S Transponder with Elementary Surveillance is required for all IFR flights of aircraft with max cruise TAS below 463 km/h and for all VFR flights above FL 95 and in CTR of big airports. Mode S Transponder with Enhanced Surveillance is necessary for all flights in Class C airspace (there is no Class A or B airspace in the Czech Republic). ADS-B Out at 1090 Extended Squitter will be required for all aircraft with MTOW greater than 5700 kg or with max TAS > 563 km/h in June 2020.

Instrument equipment is defined in CS-23 Part F Minimum Required Equipment. Basic equipment is defined in CS-23.2303 and includes airspeed indicator, altimeter, magnetic direction indicator, outside air temperature (for piston aircraft with MTOW above 2721 kg and for all turbine aircraft). Speed warning device is necessary for all aircraft with turbine engine.

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2.4 Airspace Classes in the USA and Europe

Below the general description of Airspace Classes is provided.

Class	*Type of flight*	*Separation provided*	*Service provided*	*Speed limitation**	*Radio communication requirement*	*Subject to an ATC clearance*
A	IFR only	All aircraft	Air traffic control service	Not applicable	Continuous two-way	Yes
B	IFR	All aircraft	Air traffic control service	Not applicable	Continuous two-way	Yes
	VFR	All aircraft	Air traffic control service	Not applicable	Continuous two-way	Yes
C	IFR	IFR from IFR IFR from VFR	Air traffic control service	Not applicable	Continuous two-way	Yes
	VFR	VFR from IFR	1) Air traffic control service for separation from IFR; 2) VFR/VFR traffic information (and traffic avoidance advice on request)	250 kt IAS below 3 050 m (10 000 ft) AMSL	Continuous two-way	Yes
D	IFR	IFR from IFR	Air traffic control service, traffic information about VFR flights (and traffic avoidance advice on request)	250 kt IAS below 3 050 m (10 000 ft) AMSL	Continuous two-way	Yes
	VFR	Nil	IFR/VFR and VFR/VFR traffic information (and traffic avoidance advice on request)	250 kt IAS below 3 050 m (10 000 ft) AMSL	Continuous two-way	Yes
E	IFR	IFR from IFR	Air traffic control service and, as far as practical, traffic information about VFR flights	250 kt IAS below 3 050 m (10 000 ft) AMSL	Continuous two-way	Yes
	VFR	Nil	Traffic information as far as practical	250 kt IAS below 3 050 m (10 000 ft) AMSL	No	No
F	IFR	IFR from IFR as far as practical	Air traffic advisory service; flight information service	250 kt IAS below 3 050 m (10 000 ft) AMSL	Continuous two-way	No
	VFR	Nil	Flight information service	250 kt IAS below 3 050 m (10 000 ft) AMSL	No	No
G	IFR	Nil	Flight information service	250 kt IAS below 3 050 m (10 000 ft) AMSL	Continuous two-way	No
	VFR	Nil	Flight information service	250 kt IAS below 3 050 m (10 000 ft) AMSL	No	No
* When the height of the transition altitude is lower than 3 050 m (10 000 ft) AMSL, FL 100 should be used in lieu of 10 000 ft.						

Figure 1: Airspace Classes Definition [1]

Not all airspace classes are used in every country. Schematics of airspace division in sample countries are provided in the figures below.

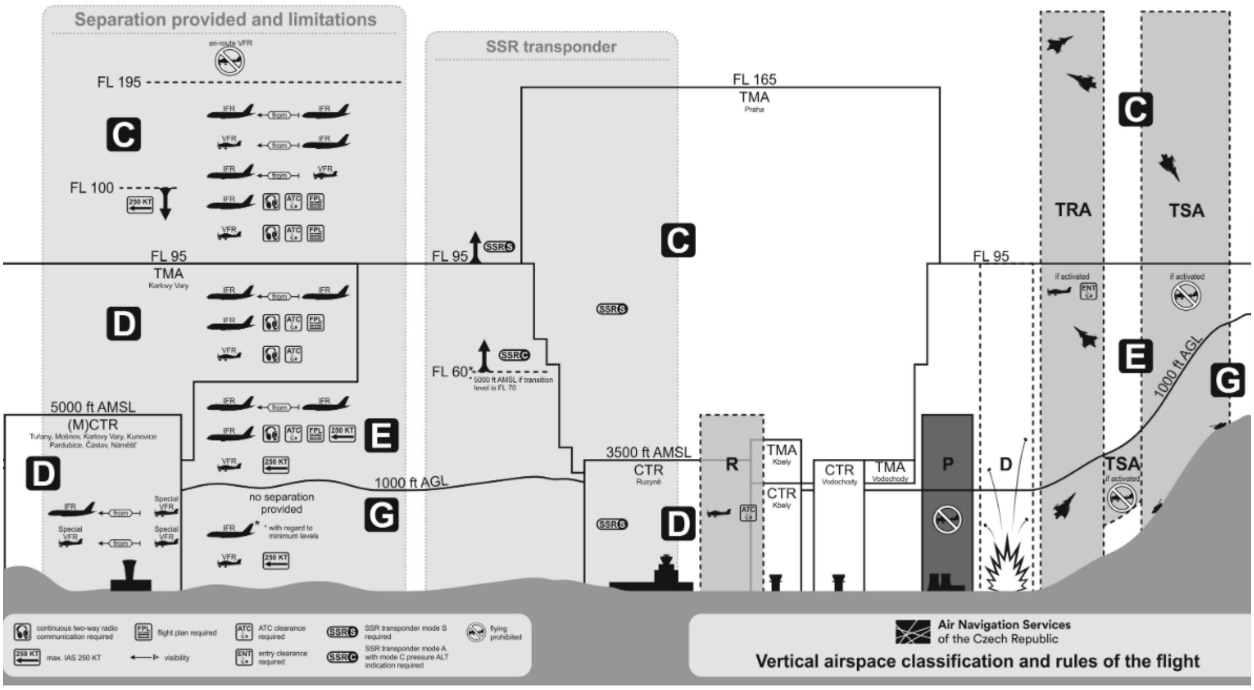

Figure 2: Vertical Airspace Classification in Czech Republic [2]

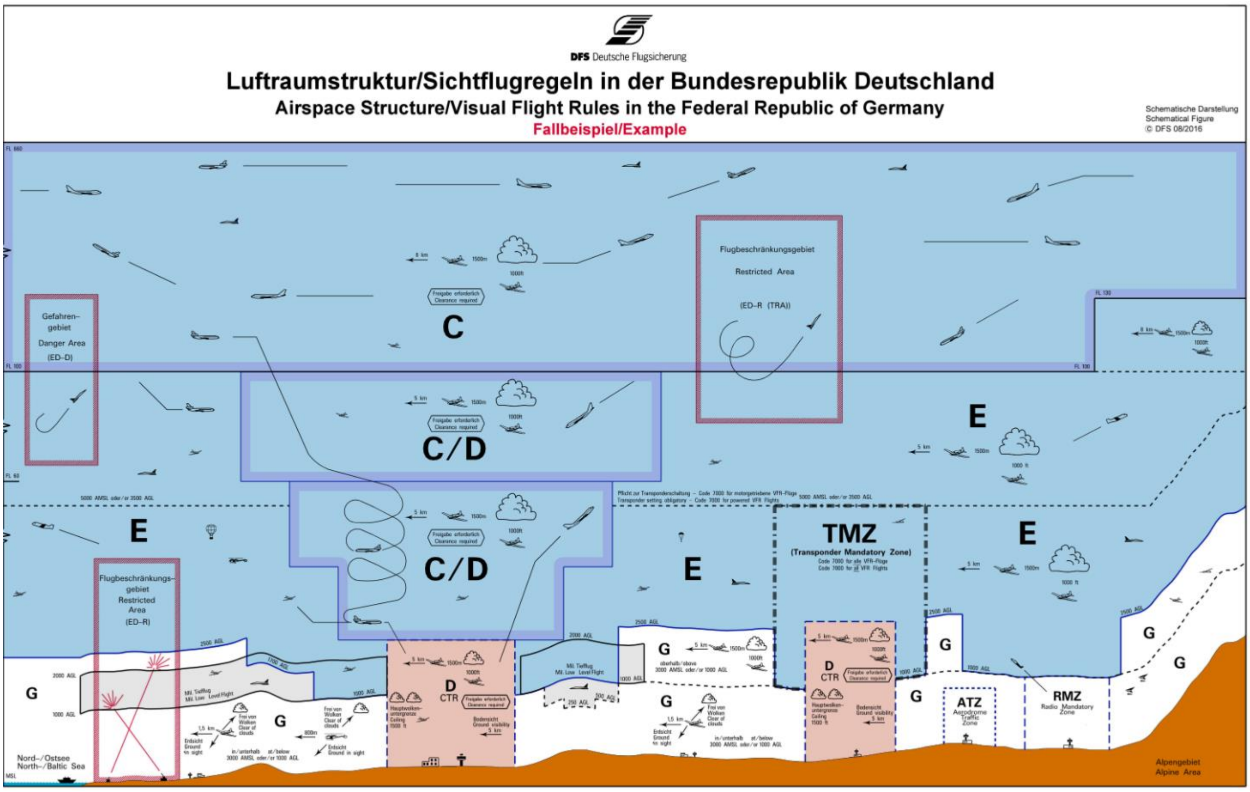

Figure 3: Vertical Airspace Classification in Germany [3]

2.5 General Aviation Part 23/CS-23 Certification Classes

General aviation aircraft certified according to Part 23 are divided into four certification classes is used. These classes are following (see details in AC 23.1309 1E):

- Class I - Typically single piston engine, MTOW < 2720 kg
- Class II - Typically multi piston, single or multi turboprop, MTOW < 2720 kg
- Class III - - All engine types, MTOW > 2720 kg
- Class IV - - Commuter, MTOW < 8620 kg, up to 19 persons

Commuters as business aircraft will not part of the analysis.

Aircraft	Class	Weight (lbs)	Ceiling (feet)	Capacity	Range (nm)	Avionics	
Piper PA-28	I	2,440	11,000	4	637	GNS 430, S-TEC autopilot	Federated Avionics
Cirrus SR-20	II	3,400	17,500	4	1,049	Avidyne PFD, Flight Max MFD, GNS430 + GNS420 (NavComm) & Garmin GPS	Federated Avionics
Piper PA-34	II	4,750	25,000	6	1,107	Dual Garmin G600	Semi Integrated Avionics
Pilatus PC-7	III	6,173	25,000	10	400	Dual Garmin G950	Semi Integrated Avionics
Grand Caravan	IV	3,000	25,000	12	918	Dual Garmin G1000	Integrated Low End Avionics
PC-12	IV	6,173	25,000	9	2,889	HON Primus APEX, single MAU with federated comm. & navigation units	Integrated Avionics
PC-24	IV	-	-	-	-	HON Primus APEX, double MAU with federated comm. & navigation units	Integrated High End Avionics

Figure 4: Classes I- IV Aircraft Examples

EASA CS-23 uses slightly different approach by defining 4 certification levels for normal-category aeroplanes as follows:

- Level 1 — for aeroplanes with a maximum seating configuration of 0 to 1 passengers;
- Level 2 — for aeroplanes with a maximum seating configuration of 2 to 6 passengers;
- Level 3 — for aeroplanes with a maximum seating configuration of 7 to 9 passengers; and
- Level 4 — for aeroplanes with a maximum seating configuration of 10 to 19 passengers.

Following tables present relationship among airplane classes, probabilities, severity of failure conditions and SW and complex HW Design Assurance Level.

Classification of Failure Conditions	**No Safety Effect**	**<----Minor----->**	**<----Major---->**	**<--Hazardous--->**	**< Catastrophic>**
Allowable Qualitative Probability	**No Probability Requirement**	**Probable**	**Remote**	**Extremely Remote**	**Extremely Improbable**
Effect on Airplane	No effect on operational capabilities or safety	Slight reduction in functional capabilities or safety margins	Significant reduction in functional capabilities or safety margins	Large reduction in functional capabilities or safety margins	Normally with hull loss
Effect on Occupants	Inconvenience for passengers	Physical discomfort for passengers	Physical distress to passengers, possibly including injuries	Serious or fatal injury to an occupant	Multiple fatalities
Effect on Flight Crew	No effect on flight crew	Slight increase in workload or use of emergency procedures	Physical discomfort or a significant increase in workload	Physical distress or excessive workload impairs ability to perform tasks	Fatal Injury or incapacitation
Classes of Airplanes:	**Allowable Quantitative Probabilities and Software (SW) and Complex Hardware (HW) Development Assurance Levels (Note 2)**				
Class I (Typically SRE 6,000 pounds or less)	No Probability or SW and HW Development Assurance Levels Requirement	$<10^{-3}$ Note 1 P=D	$<10^{-4}$ Notes 1 and 4 P=C, S=D	$<10^{-5}$ Note 4 P=C, S=D	$<10^{-6}$ Note 3 P=C, S=C
Class II (Typically MRE, STE, or MTE 6,000 pounds or less)	No Probability or SW and HW Development Assurance Levels Requirement	$<10^{-3}$ Note 1 P=D	$<10^{-5}$ Notes 1 and 4 P=C, S=D	$<10^{-6}$ Note 4 P=C, S=C	$<10^{-7}$ Note 3 P=C, S=C
Class III (Typically SRE, STE, MRE, and MTE greater than 6,000 pounds)	No Probability or SW and HW Development Assurance Levels Requirement	$<10^{-3}$ Note 1 P=D	$<10^{-5}$ Notes 1 and 4 P=C, S=D	$<10^{-7}$ Note 4 P=C, S=C	$<10^{-8}$ Note 3 P=B, S=C
Class IV (Typically Commuter Category)	No Probability or SW and HW Development Assurance Levels Requirement	$<10^{-3}$ Note 1 P=D	$<10^{-5}$ Notes 1 and 4 P=C, S=D	$<10^{-7}$ Note 4 P=B, S=C	$<10^{-9}$ Note 3 P=A, S=B

Table 2: Failure Conditions according to Airplane Class [4]

Note 1: Numerical values indicate an order of probability range and are provided here as a reference.

Note 2: The letters of the alphabet denote the typical SW and HW Development Assurance Levels for Primary System (P) and Secondary System (S). For example, HW or SW Development Assurance Level A on Primary System is noted by P=A.

Note 3: At airplane function level, no single failure will result in a Catastrophic Failure Condition. Note 4.: Secondary System (S) may not be required to meet probability goals. If installed, S should meet stated criteria.

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3 Airspace Users Typical Representatives

3.1 Manned Free Balloons

Hot-air balloon is used primarily for recreational use. Considering collisions with balloon can seem to be unlike, but some views into history leads to different opinion (in 2013 balloon accident in Egypt resulting to 19 dead, 1989 balloon collision in Australia resulting in 13 dead or balloon struck power lines and killing 16 people in Texas in 2016).

Balloon are moving as the wind blows, so collision with other balloon should not occur. Balloons are huge and move slowly, particularly slowly relative to each other. If two balloons are at same altitude and one directly blocks the wind to the other when a gust comes, it's possible for one to suddenly gain speed. This could cause speed difference, but typically not higher than a few miles per hour. Touching of balloons envelopes does not cause anything serious until baskets are involved.

Dangerous situation can occur when pilot is not informed about another balloon directly above and starts going up or when blowing wind is not stable. Local phenomena as wind gust or wind shear or local updrafts can cause horizontal speed difference between two balloons. This was cause of above-mentioned collision in Australia [1]. Naturally, collision with other traffic still represent a risk.

Balloon has no horizontal control; it is able only to go up or down to catch preferred wind.

Hot-air Balloon	
MTOW	Cca 2500 kg (with air in the balloon)
Max altitude	Cca 3000 m
Max airspeed	As wind blows
Typical avionics equipment	From nothing up to altimeter, variometer, temperature
Capacity	Typically, up to 20

Table 3: Hot-air Balloon Parameters

Example of avionics device available at the market:

Flytec 3040 is device especially for ballooning and offers altimeter, vario, clock and temperature data. It contains temperature alarms alert and it operates on 2x 9V batteries. Temperature is measured with the TT34 remote pyrometer transmitted wirelessly to the device. Dimensions are 170 x 90 x 50 mm.

Figure 5: Flytec 3040

3.2 Light GA Aircraft (CS-23)

Light GA aircraft includes Part 23 Class I and Class II aircraft. Class I are typical small single piston airplanes. As example Piper Pa-28 Cherokee was chosen. Popular airplane produced from sixtees up to now with more than 32 000 built. Installed avionics can be legacy electromechanical avionics devices or modern glass cockpit. This type of aircraft is often used for personal transport, recreational flying and for flight training.

Figure 6: Piper Cherokee Cockpit with Avidyne Entegra PFD and MFD and with federated avionics

Piper PA-28 Cherokee	
Engine	Single piston
MTOW	975 kg
Wingspan	9.2 m
Max altitude	4400 m
Max airspeed	230 km/h
Range	867 km
Typical avionics equipment	Varying from independent instruments to glass cockpit.
Capacity	4

Table 4: Part 23 Class I Aircraft Parameters

Figure 7: Piper Cherokee

Class II aircraft have the same weight limit as Class I ones, but engine is multi piston, single or multi turboprop. Typical representative is Beechcraft Baron 55, popular and still produced utility aircraft. Usage does not much differ from Class I aircraft; personal transport is the primary purpose. Capacity of five personnel enables usage as air taxi.

Typical avionics equipment is set of independent avionics products, mixture of legacy instruments together with new electronic devices.

Figure 8: Beechcraft Baron 55 and its cockpit

Beechcraft Baron 55	
Engine	Single piston
MTOW	975 kg
Wingspan	9.2 m
Max altitude	4400 m
Max airspeed	230 km/h
Range	867 km
Typical avionics equipment	Varying from set of independent instruments to glass cockpit.

Beechcraft Baron 55	
Engine	Single piston
MTOW	975 kg
Wingspan	9.2 m
Capacity	5

Table 5: Part 23 Class II Aircraft Parameters

3.3 Ultralight Aircraft (CS-23 VLA)

Ultralight aircraft is an European term for aircraft with MTOW below 450 kg used for sport and recreation purpose. In the USA, term Light Sport Aircraft is used for aircraft below 600 kg. Ultralight can be very simple home-built flying machine as the very professional aircraft as Evektor Eurostar SL. It is used as glider aerotow or for recreational flying.

Ultralight aircraft in Class G airspace does not undergo any requirements for certified avionics. They are made only for VFR flights and "see and avoid" method should be applied at all similar cases. Any collision avoidance system is up to aircraft owner.

Figure 9: Evektor Eurostar SL and its cockpit

Evektor Eurostar SL	
Engine	Single piston
MTOW	450 kg
Wingspan	8.1 m
Max altitude	6000 m
Max airspeed	240 km/h

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Evektor Eurostar SL	
Engine	Single piston
MTOW	450 kg
Wingspan	8.1 m
Range	750 km
Typical avionics equipment	Non certified glass cockpit. TL Elektronic EFIS or Dynon SkyView
Capacity	2

Table 6: Ultralight Parameters

3.4 Glider – Sailplanes

Glider as non-engined aircraft heavier than air is sometimes subject of mid-air collision. The usual reason is that gliders look for thermals and then move in similar area relative close one to another under the cloud base. Case when the sailplane is in the blind point can occur, e.g. during gliders competitions.

Wind parameters are crucial for gliding and experience of pilot plays significant role. As category representative, Schempp – Hirrth Standard Cirrus is chosen.

Modern electronic varios enable acoustic signalization of vertical speed which reduces pilot's time spend by scanning the instrument panel. Typically, the audio tone increases in frequency as the variometer shows a higher rate of climb and decreases in frequency towards a deep groan as the variometer shows a faster rate of descent. Modern varios are compensated (differing altitude change cause by lift and caused by stick input). Popular producers are LX Navigation, ILEC Gmbh, Zander of Borgelt.

FLARM as a device directly designed for sailplanes is sold solely or as a widening of GPS logger. FLARM works by calculating and broadcasting its own future flight path to nearby aircraft. At the same time, it receives the future flight path from surrounding aircraft. An intelligent motion prediction algorithm calculates a collision risk for each aircraft based on an integrated risk model. When a collision is imminent, the pilots are alerted with the relative position of the intruder, enabling them to avoid a collision [2].

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Schempp – Hirrth Standard Cirrus	
MTOW	390 kg
Wingspan	15 m
Max altitude	Cca 2500 m
Max airspeed	Cca 220 km/h
Typical avionics equipment	Mechanical airspeed indicator, altitude + variometer, slip-skid indicator,radio Optional: GPS with logger, FLARM
Capacity	One

Table 7: Glider Parameters

Figure 10: Schempp – Hirrth Standard Cirrus and its cockpit

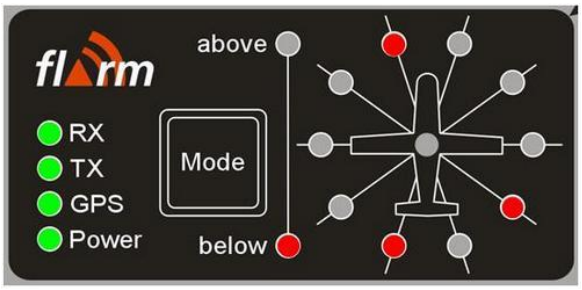

Figure 11: Example of FLARM display

3.5 Glider – Paragliders

Another example of non-engine flying object is paraglide, popular for recreational usage by many sportsmen. (Also, paraglides equipped by engine exist, but not considered in this use case).

Mid-air collisions with paraglide are documented. Most of them are collisions between two paragliders during competitions, but collision with aircraft were also reported. It is not easy to detect small paraglider from aircraft flying at higher speed. Similarly, as at balloons, local rapid changes in wind can cause this kind of collision. Another risk is landing into power lines or water area followed by tangled cords.

Paraglide	
MTOW	Cca 100 kg
Max altitude	Cca 2500 m
Max airspeed	Typically, 20 – 75 km/h
Typical avionics equipment	Altimeter required for height > 300 m above terrain, optionally variometer, GPS, radio
Capacity	One or two

Table 8: Paraglide Parameters

Example of avionics available at the market:

Digifly Archimede is altimeter and variometer especially for paragliders and hang gliders. It provides a live plot of altitude against time, which scrolls as user flies and shows how effective was climbing in a thermal. Power source is one AA battery (1.5 V). Accoustic vario function represents the instantaneous values of the vario with a modulated tone. There is an option to install also airspeed probe and then airspeed and stall alarm are provided.

Figure 12: Digifly Archimede

3.6 Part 27/CS-27 Small Helicopters

Part 27 helicopter are helicopters with MTOW up to 3 175 kg and up to nine passenger seats. Air rescue helicopters are typical example of Part 27 Helicopter. Bell 427 was chosen to represent this category. As aircraft used for police, medical or reporting purposes, most varied scenarios and trajectories have to be considered.

In the USA, there are no current mandatory requirements for ADS-B Out in VFR helicopters, although replacement transponders must be Mode S ADS-B capable. Further, any new aircraft is required to have a Mode S Extended Squitter ADS-B capable transponder if it operates in Class A, B, C or E airspace, or above 10,000ft in Class G airspace.

Some Part 27 helicopters have TCAS installed. There is also TAWS designed especially for helicopters at the market. It is, e.g., HTAWS from Thales. It uses three different databases to obtain essential information relative to airports, obstacles and terrain. The terrain database is built upon multiple database sources, including state-of-the-art Shuttle Radar Topography Mission (SRTM) mapping data.

Figure 13: Bell 427 and its cockpit

Bell 427	
Engine	Two turboshaft
MTOW	2970 kg
Length	11.4 m
Max altitude	3050 m
Max airspeed	260 km/h
Typical avionics equipment	Garmin Intercom GMA 340, NAVCOMM/GPS GNS 430, GTX 330 Mode S Transponder.
Capacity	2+7

Table 9: Part 27 Helicopter Parameters

3.7 Part 29/CS-29 Large Helicopter

Rotorcrafts which exceed Part 27 criteria, belong to Part 29 (Transport Category). These aircraft are most equipped from all lowest airspace users.

Typical example is AW 189. These helicopters are mandated to carry TCAS II in EU. Transport category helicopters are often used as military for troops transport, combat search and rescue or medical evacuation. Civil usage includes rapid deployment of personnel, heavy equipment or cargo in congested environments or fire-fighting, heavy constructions or for gas & oil industry etc.

Figure 14: AW 189

Figure 15: AW 189 Cockpit

AW 189	
Engine	Two turboshaft
MTOW	2970 kg
Length	11.4 m
Max altitude	3050 m
Max airspeed	260 km/h
Typical avionics equipment	4-axis dual-duplex autopilot, dual Flight Management System, TAWS, TCAS II

AW 189	
Engine	Two turboshaft
MTOW	2970 kg
Length	11.4 m
Capacity	2+19

Table 10: Part 27 Helicopter Parameters

3.8 Part 23 Class III Aircraft

Class III typical representative is Pilatus PC-7, single turboprop typically used for flight training including aerobatics. Its avionics is usually semi-integrated, mixing glass as Dual Garmin G50 with legacy backup electromechanical instruments.

Figure 16: Pilatus PC-7 and its cockpit

3.9 Drones

There are more options how to classify drones. Categorization can be done per weight, purpose, construction etc. Since this report is focused on CNS capabilities/needs of lowest airspace users, the type of operations tightly coupled with drones' construction is key. Basic categories are fixed wing drones, multicopters (multirotor) and other systems as hybrid drones or drones with turbo fans. Multicopters differ in number of propellers. Tricopters or quadrocopters are more agile whereas octopers are very stable.

Next possible division is into remotely controlled and autonomous RPAS/drones. The autonomous aircraft are currently used for military purposes, but high rise e.g. in area of transport small packages is expected. The autonomy can vary from full autonomous operation to fully controlled by a remote pilot. Differences between fixed-wing drones and multirotor drones are important for the different applications consumers want to use the drone for. For example, multirotor drones do not need a landing strip, make less noise than their fixed-wing counterparts and can hover in the air. Fixed-wing drones can fly faster and are more suitable for long distances than their multirotor counterparts. Hybrid drone uses multiple rotors to take-off and land vertically but also has wings so it can fly longer distances. These characteristics determine which of these drone types to use for a specific application.

Fixed-wing Drones

Fixed-wing is a term mainly used in the aviation industry to define aircraft that use fixed, static wings in combination with forward airspeed to generate lift. Examples of this type of aircraft are traditional airplanes, kites that are attached to the surface and different sorts of gliders like hang gliders or paragliders. Even a simple paper airplane can be defined as a fixed-wing system. An example of a fixed-wing drone is the widely-used Raven.

The main purpose of the Raven is surveillance and it can be controlled remotely or pre-programmed for autonomous operation. The Raven has a width of 1.4 m, weighs about 2 kg, and can stay operational for 60–90 min within a range of 10 km. It is equipped with an optic and an infrared camera. Like regular model airplanes, the Raven can be launched by throwing it in the air. It lands by gliding toward a pre-programmed landing site and can compensate for the impact when hitting the ground by falling apart.

Figure 17: Raven

Raven	
Power	Battery cells
MTOW	2 kg
Size	1.4 m
Max altitude	150 m
Max airspeed	30 - 80 km/h
Range	10 km
Payloads	Forward and Side-Look EO Camera Nose, Electronic Pan-tilt-zoom with Stabilization, Forward and Side-Look IR Camera Nose

Table 11: Fixed-wing Drone Parameters

Multicopter Drones

Multirotor systems are a subset of rotorcraft. The term rotorcraft is used in aviation to define aircraft that use rotary wings to generate lift. A popular example of a rotorcraft is the traditional helicopter. Rotorcraft can have one or multiple rotors. Drones using rotary systems are almost always equipped with multiple small rotors, which are necessary for their stability, hence the name multirotor systems. A popular example of these multirotor drones is the widely used Phantom drone made by the Chinese company DJI. The Phantom drone is a multirotor drone with four rotors and is mainly built for recreational purposes. The drone comes with a camera and can be controlled using a smartphone or a WiFi controller. The smartphone can also control the camera to move and make pictures or record video. The Phantom can fly at around 54 km/h and it can operate for about 25 min. Just by programming the flight altitude and certain waypoints the drone can take-off, land, make recordings, and return automatically. Its weight is 1.4 kg.

Phantom	
Power	Battery cells (LiPo)
MTOW	1.2 kg
Size	35 cm
Max altitude	150 m
Max airspeed	36 km/h
Range	10 km
Payloads	Camera

Table 12: Multicopter Drone Parameters

3.10 **Urban Air Mobility**

Urban air mobility brings additional types of aircraft – electric Vertical Take Off and Landing (eVTOL) vehicles. There are several types of these vehicles under active development and/or certification process in Europe: Lilium Jet, Vertical VX4, Pipistrel Nuuva V300, Volocopter, etc. They have a potential to support large scale of use cases, the initial deployment being typically focused on manned (pilot onboard) air taxi or cargo, and unmanned cargo. Operational ranges are from tenth of kilometres (Volocopter) up to 200-300 kilometres (Lilium Jet, Pipistrel Nuuva V300). Initial certification either follows the similar approach as GA for manned operations, or new regulatory framework being developed for drones/RPAS based on operational risk assessment (typically using SORA methodology) for unmanned cargo operations.

For illustration, trial operation of a manned air taxi was run a few years ago in Dubai by German Volocopter Company. Volocopter 2X made by this company is equipped by 18 fixed-pitch propellers, each powered by its own electric motor. Accommodation is two-seats-in side-by-side configuration in an enclosed cockpit with a windshield. The aircraft has a typical empty weight of 290 kg and a gross weight of 450 kg, giving a useful load of 160 kg for pilot, passenger and baggage. Noise level is 65 dB.

Volocopter 2X	
Power	18 × three-phase PM synchronous brushless DC electric motors
MTOW	450 kg
Size	9.15 x 2.15 x 3.20 m
Max altitude	150 – 1500 m
Max airspeed	100 km/h (limited time)
Range	27 km
Payloads	160 kg, 1+1
Certification	Certified as ultralight aircraft

Figure 18: Urban Air Mobility Vehicle Parameters

Certification Aspects:

As stated above, UAM aircraft may significantly vary in many parameters – MTOW, type of operation, number of passengers, atc. Generally, traditional Part 21.17(a) method can be used for aircraft falling into existing categories, for other the Part 21.17(b0 is applicable. Additional requirements will be given for example per propulsion type (Part 33 Engine) [7].

Issues related to certification can significantly slow down the development and especially deployment of the UAM. There are many innovative functions in UAM design which do not simply fit into existing certification approach.

Certification projects working on this topic run. For example, FAA Order 8000.71 defines a Hybrid vehicle, "a heavier-than-air aircraft that is supported at vertical takeoff, vertical landing, and low-speed flight by the dynamic reaction of the air against its rotors or thrust and in horizontal flight by the dynamic reactions of air against its wings (i.e., the tilt-rotor aircraft)" [14]. EUROCAE WG 112 and EASA are intensively working on establishing solid certification framework for VTOL vehicles in Europe.

issues related to certification can significantly slow down the development of the UAM.

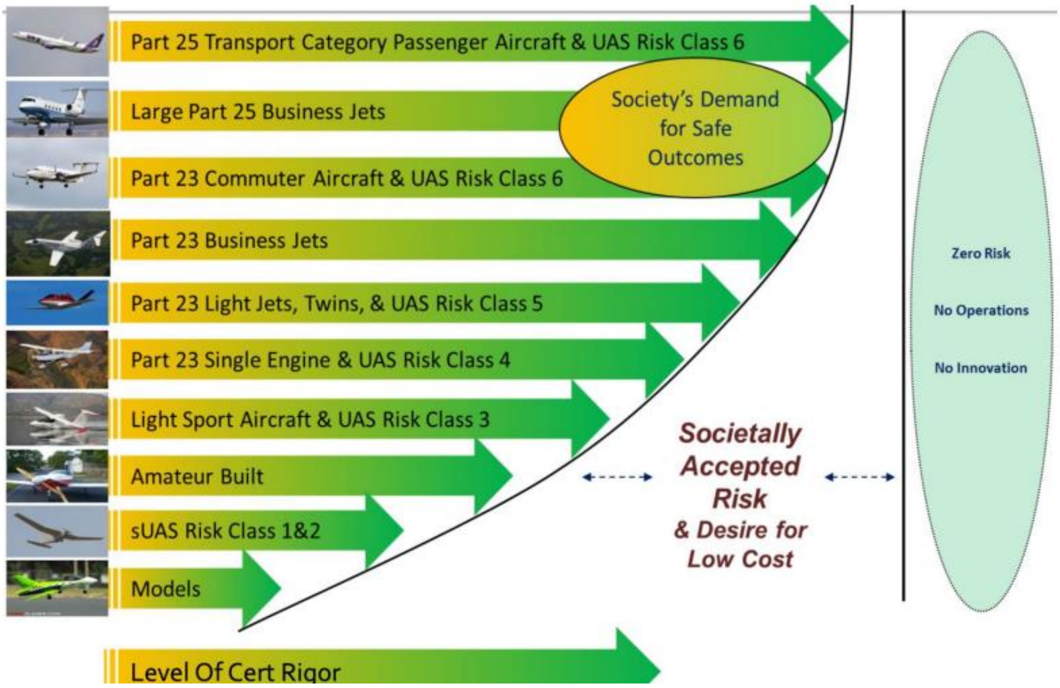

Figure 19: Trade-off between risk tolerance and level of certification rigor [7]

4 Environment Typology

This section divides considerable environments into four types. These environments were established to examine potential risk of mid-air collision and collision with obstacles or terrain. Environment is divided horizontally (above city or above rural area) and vertically.

Altitudes higher than 4,000 ft are not discussed here since they are not relevant for the project's discussion of cellular network, however, it does not mean that many of the users discussed in the previous chapter cannot operate more or less often in these altitudes.

Environment	Alt [ft]	Airspace Class	Predominant Traffic
Very Low Level – Urban Area	0 - 500	G	UAV VLL – Urban Area Small rotorcraft – Part 27 Manned Air Taxi
Very Low Level – Rural Area	0 - 500	G	UAV VLL – Rural Area Small rotorcraft – Part 27 Large rotorcraft – Part 29 Urban Air Mobility
Low Altitude	500 - 4000	G	General Aviation – SLA, VLL, Part 23 Small rotorcraft – Part 27 Large rotorcraft – Part 29Urban Air Mobility Drones – "VFR like" Drones – IFR capable IAS up to 250 kt
Proximity to Airport	0 - 1500	D	General Aviation – SLA, VLL, Part 23 Transport Airplanes – Part 25 Small rotorcraft – Part 27 Large rotorcraft – Part 29 Drones – "VFR like" Drones – IFR capable Urban Air Mobility

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5 Summary

Traffic in low and very low altitudes is heterogenous and has a potential to be even more heterogenous in near future. Mixed traffic is undoubtedly more efficient than traffic in segregated spaces. This situation brings new traffic challenges and requirements for CNS equipment. To design new efficient CNS devices capable of communicating with traditional avionics equipment and infrastructure while leveraging new available technologies, it is important to deeply understand current situation and have a good overview of equipment, capabilities, and operations of particular airspace users.

Eleven categories of airspace users of interest were analyzed and described in this document with focus given on typical parameters and installed avionics. Operational and business aspects will be discussed in the document D4.2 Business Concept per User Groups with resulting requirements to CNS equipment.

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