RAdar para Detection and Avoidance em Veículos Aéreos Não Tripulados

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Editor:	João M. Gil (TWEVO)
Authors:	João M. Gil (TWEVO), Carlos Ribeiro (TWEVO), Eduardo Castañeda (TWEVO)
Internal reviewers:	Carlos Ribeiro (TWEVO), João Reis (IT), Rafael Caldeirinha (IT)
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SUMMARY (EN):

This Deliverable systematically reports on the international regulation behind the RADAVANT project. Such regulation regards spectrum and flight rules. It builds upon the initial project references, and helps to further structure the project and our decisions. It includes future insight, since many of its aspects are currently being discussed and decided, at the various institutional levels, worldwide. We conclude on the spectrum bands to be used in the radar block, the data-link block. The report also adds considerations on the final DAA capacity, in parallel with the envisioned targets, applications, categories, classes and scenarios.

SUMÁRIO (PT):

Este Entregável sistematicamente reporta sobre a regulamentação internacional por detrás do projeto RADAVANT. Essa regulamentação diz respeito ao uso do espectro e regras para o voo. Constrói-se sobre as referências iniciais do projeto, para melhor ajudar a estruturar o projeto e as nossas decisões. Inclui uma visão virada para o futuro, já que muitos aspetos estão atualmente a serem discutidos e decididos, nos vários níveis institucionais, no mundo. Concluímos sobre que bandas serão usadas no bloco de radar e no bloco do data-link. O relatório ainda acrescenta considerações sobre nas capacidades finais de DAA, em paralelo com os objetivos, as aplicações, categorias, classes e cenários perspetivados.

Keyword list: UAV, Drones, Radar, Regulation, Spectrum, DAA, Professional, Inspection, Surveying, Surveillance

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List of Acronyms

AltMoc	Alternative Means of Compliance
ASSURE	Alliance for System Safety of UAS through Research Excellence
BVLOS	Beyond Visual Line-of-Sight
C2	Command and Control
CONOPS	Concept Of Operations
COTS	Custom-Off-The-Shelf
CEPT	European Conference of Postal and Telecommunications
DAA	Detect And Avoid
DFS	Dynamic Frequency Selection
DPC	Dynamic Power Control
e.i.r.p.	Effective Isotropic Radiated Power
EC	European Commission
EU	European Union
EP	European Parliament
e.r.p.	Effective Radiated Power
EASA	European Aviation Safety Agency
ECC	Electronic Communications Committee
EMC	Electromagnetic Compatibility
FAA	Federal Aviation Authority
FCC	Federal Communications Commission
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
NAA	National Aviation Authority
NBR	New EC Basic Regulation
p.s.d.	Power Spectral Density
RED	Radio Equipment Directive
RLAN	Radio Local Access Network
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Aircraft System
RPASP	Remotely Piloted Aircraft Systems Panel
SDR	Software-Defined-Radio
SRD	Short Range Device
SRR	Short Range Radar
STS	Standard Scenario
SWAP-C	Size, Weight And Power, and Cost
TA	Technical Annex
TCAM	Telecommunication Conformity Assessment and Market Surveillance Committee
TTT	Transport and Traffic Telematics
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
U-NII	Unlicensed National Information Infrastructure
US	United States
UWB	Ultra-Wideband
VLOS	Visual Line-of-Sight
WRC	World Radiocommunication Conference

1. Scope

The RADAVANT project aims to research and develop a joint radar sensing-communication system to improve flight safety and control of Unmanned Aerial Vehicles (UAVs), dedicated to utilities and infrastructure inspection. The system will be designed to operate particularly in Beyond Visual Line-of-Sight (BVLOS) and high interference scenarios, where detection and avoidance is most critical. The conception, construction and deployment of such a system will result in more cost efficient inspection services and add more value to other services delivered by UAVs.

The aim of this Deliverable is to systematically report on the international regulation behind our RADAVANT project. It builds upon the initial project references, and helps to further structure the project and our decisions. It includes future insight, since many of its aspects are currently being discussed and decided, at the various institutional levels, worldwide. This deliverable simultaneously serves as a work anchor, always leaving open doors to future evolution or changes, if required. This Deliverable also helps to make RADAVANT most adequate towards present Regulation. But, further, it also envisages to be useful to contribute to Regulation, in the future, as well as towards the market. For this, we direct attention towards the global worldwide scope, as well as towards the European and the US contexts.

Within the RADAVANT overall context (see Figure 1), the Deliverable focuses on a) Spectrum use for the Radar component, b) Spectrum use for the Data-link component and c) Detect And Avoid (DAA) and Radar in UAVs.

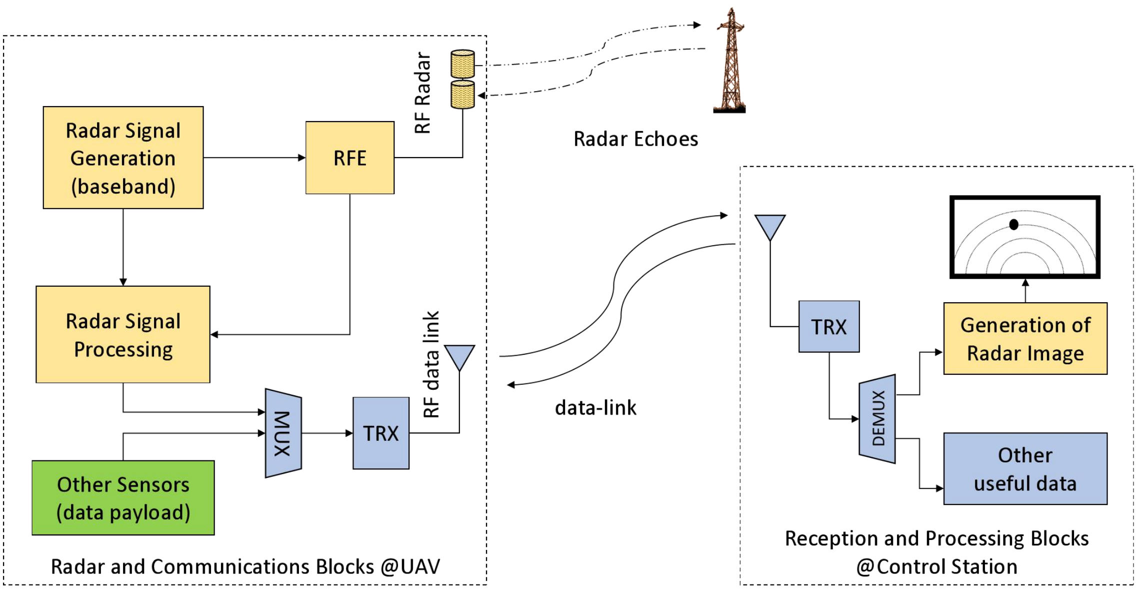

Figure 1 - Fundamental RADAVANT blocks (Radar blocks in yellow, Data-link blocks in blue).

2. Spectrum use for the RADAVANT Radar Component

2.1. 24GHz ISM band

The RADAVANT Radar component falls into the ISM equipment category. The use of the 24 GHz ISM band (24-24.25 GHz) is supported by the ITU Radio [ITU RR 5.138 e 5.150], under the provisions of ITU RR 5.13 [source], "Administrations shall take all practicable and necessary steps to ensure that radiation from equipment used for industrial, scientific and medical applications is minimal and that, outside the bands designated for use by this equipment, radiation from such equipment is at a level that does not cause harmful interference to a radiocommunication service and, in particular, to a radionavigation or any other safety service operating in accordance with the provisions of these Regulations".

In Europe, ERC Recommendation 70-03, Annex 1, m) [source] also establishes the use of such band under the Non-Specific Short Range Devices (SRDs), with maximum 100 mW/20 dBm e.i.r.p. . This has been verified to be the case of National rules in Portugal [source], Spain [source], Germany [source], France [source], Belgium [source]. Similarly, its regulation should be verified for a larger set of EU countries where we envisage our target market, since the EC 2011/829/EU decision [source] indicates a narrower 24 GHz band (24.15-24.25 GHz only), for ISM purposes. EC 2006/771/EC decision, 3. of Article 3 [source], also as amended by EC 2011/829/EU decision, states that "This Decision is without prejudice to the right of Member States to allow the use of the frequency bands under less restrictive conditions than specified in the Annex to this Decision.", and point (7) "Member States may allow, at national level, equipment to operate under more permissive conditions than specified in this Decision. However, in this case such equipment could not operate throughout the Community without restrictions and would therefore be considered as 'Class 2' equipment under the classification in the R&TTE Directive.".

In the US, the use of the ISM 24GHz band (24-24.25 GHz) is possible, and the RADAVANT radar also fits in to the ISM equipment category. There is no explicit power limit [source, §18.305 a)] and the available bandwidth is 250 MHz, as with in most countries in Europe.

For this, RADAVANT will make use of the 250MHz band, from 24 to 24.25 GHz, as an ISM System, for the main operation of its radar component, always keeping in mind any specific national regulation of the country of deployment. The band of 250 MHz poses the problem of achieving the required spatial resolution, as defined in the RADAVANT Technical Annex (TA). The RADAVANT Consortium will put forward a solution. And though, at the same time, RADAVANT will harmoniously fit into the European and US markets (and others).

2.2. Context - Other uses and other bands

In Europe, it is important to be aware of the following context, in the present and in the future:

- the allowed use of the 24.25-26.65 GHz band for Short Range Radars (SRRs) in automotive, under the "Transport and Traffic Telematics (TTT)" uses, is being phased-out [source, ERC Recommendation 70-03, Annex 5, c2]. This is not the case of nearby bands, and automotive SSRs may still be allowed to work in the 24 GHz ISM bands. The general, and in our view, the correct interpretation is that "automotive" refers to terrestrial vehicles. Definitely not including UAVs. It may anyhow, in the future, include UGVs;

- The RADAVANT Consortium should anyhow pay attention to the follow-up of such phasing-outs, since in particular these also imply closing Ultra-Wideband (UWB) services around the 24 GHz band;
- "Radiodetermination Applications" [source, ERC Recommendation 70-03, Annex 6] does not fit our radar use, since it also applies to automotive uses. It also includes several bands around the 24 GHz band, with several also being phased-out;
- Following ERC Recommendation 70-03 [source, Annex 5, f2], it is interesting to note that the 76-77 GHz band is destined also for TTTs, for obstacle detection radars for rotorcraft use. A quadcopter UAV does seem to fit into this category. Nevertheless, the ETSI EN 303 360 regulation [source] explicitly targets "manned rotorcraft" use. Also, Regulation EU 2018/1139 [source] defines unmanned aircraft as "any aircraft operating or designed to operate autonomously or to be piloted remotely without a pilot on board;". Respective ETSI standards [source] also explicitly target automotive use, as well as the Portuguese National Regulation (harmonized use of the 76-77 GHz band for infra-structure and terrestrial vehicles [source]);
- Annex A, h) of the ERC Recommendation 70-03 [source] also includes the 77-81 GHz band, dedicated for automotive SRRs, following ECC/DEC/(04)03 decision [source].

In parallel, in the US, the context is the following:

- As with the European case, there are several bands around the 24 GHz that explicitly refer to the automotive use, terrestrial, also in the phasing-out phase [source, FCC Rule §15.37, l) and m)]. These are the 23.12-29 GHz and the 22-29 GHz bands;
- The use of radar for vehicles, in the 76-81 GHz band, is regulated under FCC 47CFR95, subpart M [source]. Their use in aerial vehicles is not allowed, in flight (§95.3331 e §95.3333). As in Europe, this fits the global decision of dedicating the 70 GHz frequencies for the terrestrial automotive industry;
- Similarly, the use of frequencies between 57 and 71 GHz is not allowed in aerial systems, in flight [source, §15.255 b) 2 ii)], "(b) Operation on aircraft is permitted under the following conditions: (1) When the aircraft is on the ground. (2) While airborne, only in closed exclusive on-board communication networks within the aircraft, with the following exceptions: (i) Equipment shall not be used in wireless avionics intra-communication (WAIC) applications where external structural sensors or external cameras are mounted on the outside of the aircraft structure. (ii) Equipment shall not be used on aircraft where there is little attenuation of RF signals by the body/fuselage of the aircraft. These aircraft include, but are not limited to, toy/model aircraft, unmanned aircraft, crop-spraying aircraft, aerostats, etc.". For this, the use of 60 GHz frequencies is clearly not possible in the US. The reasons for such are put forward by the Federal Register/FCC in [source, of 1/Feb/2018].

3. Spectrum use for the RADAVANT Data-link Component

3.1. Possible Bands

Our decisions, under the RADAVANT project and dealing with the data-link block, already make use of TWEVO's public White Papers on the matter [source], [source]. These are, in their most, extendible to the RADAVANT's data-link. Again, it is important to have a global view of the issue, so as to make RADAVANT compatible with the US and European markets (among others).

Keeping in mind that the data-link will primarily work to transfer the radar data to the control station, in the down-link, the main unlicensed bands available for us are the following [for Europe, ERC/REC 70-03, source] and [for the US, FCC 47CFR15, §15.247, §15.249, source; FCC 47CFR15, subpart E, source]:

- EU: 865 - 868 MHz, for *non-specific SRDs* (SRDs)
- EU: 2400 - 2483.5 MHz, for *Wideband Data Transmission Systems* (SRDs) + RLANs at 2.4 GHz
- EU: 5150 - 5350 MHz, for *Wideband Data Transmission Systems* (SRDs) + RLANs at 5 GHz
- EU: 5470 - 5725 MHz, for *Wideband Data Transmission Systems* (SRDs) + RLANs at 5 GHz
- EU: 5725 - 5875 MHz, for *Tracking, Tracing and Data Acquisition* (SRDs)
- US: 902 - 928 MHz, for *non-application-specific radio applications*
- US: 2400 - 2483.5 MHz, for *non-application-specific radio applications*
- US: 5725 - 5875 MHz, for *non-application-specific radio applications*
- US: 5150 - 5250 MHz, for U-NII (*Unlicensed National Information Infrastructure*, RLANs)
- US: 5250 - 5350 MHz, for U-NII (*Unlicensed National Information Infrastructure*, RLANs)
- US: 5470 - 5725 MHz, for U-NII (*Unlicensed National Information Infrastructure*, RLANs)
- US: 5725 - 5850 MHz, for U-NII (*Unlicensed National Information Infrastructure*, RLANs)

The use of these bands implies following distinct normative requirements, depending on the frequency and use, following the norms and rules indicated above. These are subject to further technical specifics, standards and sub-rules. The parallelism between the European and US is clear and large, easing the reach of both markets. Nevertheless, the differences are very relevant, e.g., regarding the restriction to the mobile aeronautical use and maximum powers.

The use of these bands for communication purposes in the drone/UAV context, between the UAV and the control station, is not only being defined (technically and legally, also at the governmental level), but also is subject to fast changes and various interpretations of what is still undefined. It is critical to make a periodic consultation of all relevant documents, in the present and future, during the RADAVANT project.

3.2. Context - the specific RADAVANT UAV use

Generally, the UAV band use restrictions in Europe are greater than in the US. All of these, anyhow, generally follow ITU's rules and resolutions from World Radiocommunication Conferences (WRCs). There are important specific groups and discussions on the spectrum use in other relevant global bodies, such as International Civil Aviation Organization (ICAO). Even though ICAO's role does not directly deal with spectrum, ICAO's Frequency Spectrum Panel is active in the matter.

Use of Spectrum in Europe

The recent EU Regulation 2018/1139 of the European Parliament and of the Council, 4 July 2018 [source] establishes that all radio equipment in unmanned aircraft shall follow the Radio Equipment Directive (RED) 2014/53/EU [source] and the Electromagnetic Compatibility (EMC) Directive 2014/30/EU [source]. The RED directive specifies the rules for functioning, certification and commercialisation of any radio product. It defines several classes and sub-classes of equipment: Class 1 is the "radio equipment that can be operated without any restriction in the whole EU", Class 2 is "radio equipment whose putting into service or use is subject to restrictions. Examples of such restrictions are: frequency available and allowed for that application in certain Member States only; individual licence needed to use the specific radio equipment and compliance with attached conditions, as e.g. the need of an operator certificate; indoor use only;" [RED Guide, June 2018, source]. In the case of RADAVANT, there are some situations for which our product will fit into a Class 2 equipment, i.e., to function with certain restrictions. This should not pose a problem to the Consortium, in the technical/regulatory/commercial views, since we have found a progressive alignment between the professional use and certain flight conditions (see the description on DAA regulation, below) - the inclusion of specific restrictions for spectrum use by the data link does not seem to pose significant limitations to such already limited and controlled UAV operations.

Concerning the 865-868 MHz band, for non-specific SRDs, the use of the whole 3 MHz band allows resorting to maximum power spectral density (p.s.d.) of 6.2dBm/100kHz [ERC/REC 70-03, Annex 1, band h1.2, source]. Nevertheless, following both the EC 2011/829/EU decision and Telecommunication Conformity Assessment and Market Surveillance Committee (TCAM) [source], the RADAVANT data link will be able to use such band, subject to restrictions, i.e., as a Class 2 equipment.

In respect to using the 5150 - 5350 MHz band, for Wideband Data Transmission Systems/RLANs, there is the limitation to the indoor use only [ECC/DEC/(04)08, source]. The use of the 5470 - 5725 MHz band, also for Wideband Data Transmission Systems/RLANs), is open for indoor and outdoor. Nevertheless, the TCAM explicitly forbids the use "for communication between planes and earth stations". Further, ECC/DEC/(04)08 states that both of those bands have been allocated to the *mobile service except aeronautical mobile* service on a primary basis in all three regions by World Radiocommunication Conference 2003 (WRC-03), taking into account the need to protect primary services in these frequency bands. Such leads to the CEPT/ECC/DEC interpretation, put forward in the very recent ECC Report 268, *Technical and Regulatory Aspects and the Needs for Spectrum Regulation for Unmanned Aircraft Systems (UAS)* [source, Feb 2018], in that such bands are not allowable for the communications between the UAV and the control station. It is, therefore, the consortium's decision that RADAVANT shall not primarily operate in the Wideband Data Transmission Systems/RLANs 5150-5250 MHz, 5250-5350 MHz and 5470-5725 MHz bands (in Europe).

Last, but not least, the unlicensed 2400 - 2483.5 MHz band, for *Wideband Data Transmission Systems* (SRDs) + RLANs at 2.4 GHz, and the 5725 - 5875 MHz band, for *Tracking, Tracing and Data Acquisition* (SRDs) are also of use for RADAVANT's data link, in Europe. For that, RADAVANT's data link must be prepared for a higher level of security and resilience, compared to other communication services sharing the same bands.

Use of Spectrum in the US

In seeing that the above aeronautical use restrictions do not apply in the US context, for the Unlicensed National Information Infrastructure (U-NII)/RLANs [FCC 47CFR15, subpart E rules, [source], the above decision on the 5150-5250 MHz, 5250-5350 MHz and 5470-5725 MHz bands is likewise adequate, to broaden our target towards the US market. For such band uses, RADAVANT's data link must be prepared to deploy Dynamic Frequency Selection (DFS) and even Dynamic Power Control (DPC), in the US.

As in Europe, the 902 - 928 MHz and the 2400 - 2483.5 MHz band, for *non-application-specific radio applications*, and the 5725 - 5850 MHz band, for U-NII/RLANs, are also of use for RADAVANT's data link.

Other UAV-Specific Implications, related to Spectrum

The ECC Report 268 also makes interesting bridges between the European Parliament (EP), the European Commission (EC), the European Aviation Safety Agency (EASA), the Federal Aviation Authority (FAA), and also ICAO, largely in confirmation with what has been the planning for the RADAVANT project, as well as Twevo's plan towards the UAV/drone market. The spectrum issues are very closely intertwined with UAV flying regulations:

- There is a clear distinction between professional and non-professional use, following the categorisation of operations as *Open* or *Specific* (further described in the following section on DAA Regulation);
- There is a fit between the base Open subcategories A0 and A1 for non-professional use, mostly using the unlicensed shared 2400-2483.5 MHz and 5725-5875 MHz bands;
- While linking subcategories A0 and A1 to general authorisations in terms of spectrum, subcategories A2 and A3 fall into the professional use (for which competence/examination are needed), also possibly requiring the use of other, licensed and specific UAV use bands;
- Independent of the categories and subcategories of operation, the report emphasises the need for the use of dedicated, licensed spectrum bands, for professional UAV use, evolving to a safer market;
- The need for resilience in relation to interference or intentional sabotage, in particular for the Command and Control (C2) radio link, is stressed. Such radio systems must incorporate security measures including solid encryption, with implications on the bandwidth and channelling of these links;
- Such larger demands for the C2 link should not apply to other data payload channels, even in the case of sharing bands. Take, for example, ITU's contribution to the definition of spectrum requirements for C2, *Characteristics of unmanned aircraft systems and spectrum requirements to support their safe operation in non-segregated airspace* [ITU-R M.2171 (12/2009), source].
- There are no specific allocated frequencies for UAVs/drones, among the several national frequency allocation tables, in Europe;
- There is a profusion of illegal radio use, due to the over-restrictive power levels;
- The general view of the ECC Report is that it is necessary to provide new spectrum opportunities, for new and innovative, safe and professional UAV use;
- There are several future possibilities for the use of spectrum for C2, around 800MHz, 2 and 5 GHz, fitting our RADAVANT roadmap (from EASA, EC, ICAO and ITU/WRCs contributions);
- Already in the present, some EU State Members are making use of RR 5.443C (WRC 2012), concerning the 5030 - 5091 MHz band by the aeronautical mobile service [source], for the licensed use in UAVs. ITU has issued a report on the use of this band for the UAV use, LOS and non-payload communications link(s) [source];

- In the US, similarly, there are proposals for the expansion towards other bands, some in the discussion and amendment phases, e.g., for the 4940 - 4990 MHz bands, for data payload [source], [source] and [source], for the use of professional UAVs;

4. Relevant DAA Regulation and Definitions

In the matter of DAA, there are contributions from many of the players involved - ITU, ICAO, EC/EP, CEPT, EASA, FCC, FAA and JARUS - further adding diversity at the National Aviation Authority (NAA) levels. Some of those bodies deal more with the airspace issues, others with the spectrum use. Some are dealing with the whole, fostering a global harmonization effort. For the RADAVANT project, on the whole, it is their whole contribution towards the establishment of a future DAA mindset that is important to this Consortium.

4.1. EC/EP

Recent Regulation EU 2018/1139 [source] refers to the certification and use of UAVs in the European airspace. Besides the issues already covered above, the most important for us to follow on the New EC Basic Regulation (NBR) [source] are the following:

- "common EU rules for all unmanned aircraft, independently from their maximum take-off mass";
- "Rules must be Proportionate and Risk-Based";
- "Certification: required only when nature of risk and type of operation justify such requirement";
- "Use of market surveillance mechanisms provided by Union product harmonization legislation to reach adequate level of safety (CE Marking)";
- "Possibility to declare compliance with relevant industry standards, where this is considered to ensure an acceptable level of safety";
- "State operations excluded from NBR - but can Opt-in";
- "A degree of flexibility should be provided for the Member States to taking into account local characteristics".

4.2. CEPT, EASA, JARUS, FAA, ITU and ICAO

A very recent Workshop between CEPT and EASA [CEPT Workshop on spectrum for drones / UAS Summary, Outcome, APs for ongoing activities, May 2018, source] has contributed for further discussion on DAA and spectrum, again showing the correct alignment of the RADAVANT project. According to the outputs from that Workshop, EASA further presents its broader view of the context:

- The Open category will be for Visual Line-of-Sight (VLOS) UAV operations, maximum 120 m height, maximum UAV weight of 25kg, resorting to shared, unlicensed radio bands. It is our understanding that, for BVLOS, the tendency is for the use of specific, licensed, unshared bands, for maximum safety and resilience;
- For the Specific category, standard scenarios need to be defined;
- Sense-and-Avoid/DAA systems are still in the R&D phases, with the tendency to use Custom-Off-The-Shelf (COTS) solutions. For low-altitude UAV use, these are still immature;
- The use of several technologies provide a potentially safer approach using data fusion, aiding the pilot to verify and decide on the intervention on his display;

- Detection must also involve radio communications, combining acoustic, thermal/IR, optical and radar technology, especially in the case of BVLOS operation;
- Concerning the category/subcategory/class reasoning, there is a large alignment between EASA's category/class proposals and subsequent EC/EP lawmaking, as well as with the FAA's Small UAS Rule (14 CFR part 107) [source] and [source], made applicable in the US after August 2016. We further add that such coordination is further extended towards the global-scale Joint Authorities for Rulemaking on Unmanned Systems (JARUS) group, as well as ICAO's rules.

The general global alignment in the UAV flight and control rules aids in the guidance of our RADAVANT's work. For this, we are more directly following EASA's proposals, always keeping in mind the outputs from all other rulemaking bodies (in the present and in the future).

Operation Categories and RADAVANT

The recent keynote [source] and the Opinion No. 01/2018 [source] from EASA summarise and update the evolutions of regulation processes between EASA and the EC/PE. Namely, concerning the following:

- The definition of categories of operation: *'Open' category* (low risk), *'Specific' category* (medium risk) *and 'Certified' category* (higher risk), Figure 2:

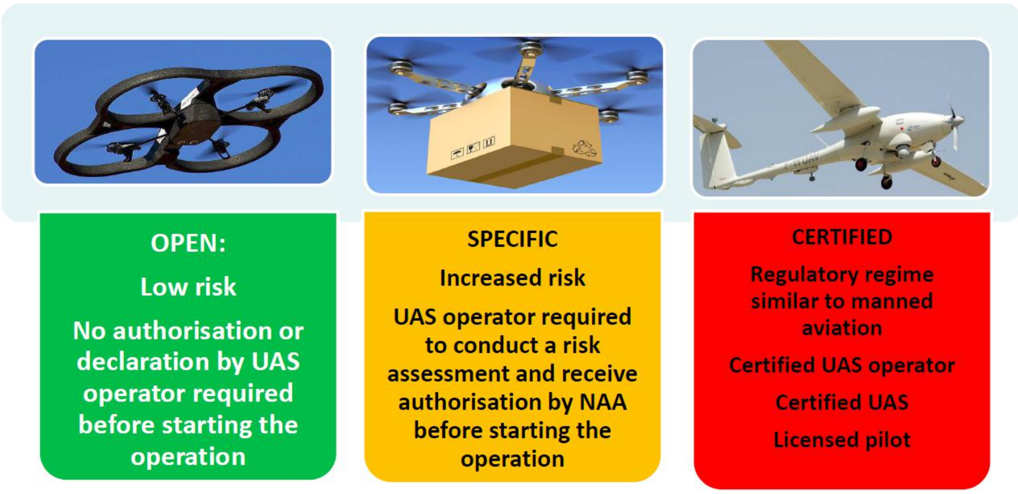

Figure 2 - The three operation categories defined by EASA [source].

i. "'Open' category (low risk): Safety is ensured through compliance with operational limitations, mass limitations as a proxy of energy, product safety requirements and a minimum set of operational rules." + "through a combination of limitations, operational rules, requirements for the competency of the remote pilot, as well as technical requirements for UAS, such that the UAS operator may conduct the operation without prior authorisation by the competent authority, or without submitting a declaration;"

ii. "'Specific' category (medium risk): Authorisation by an NAA, possibly assisted by a QE, following a risk assessment performed by the operator. A manual of operations lists the risk mitigation measures" + "through a system that includes a risk assessment being conducted by the UAS operator before starting an operation, or an operator complying with a standard scenario, or an operator holding a certificate with privileges.";

iii. "'Certified' category (higher risk): Requirements comparable to those for manned aviation. Oversight by NAA (issue of licences and approval of maintenance, operations, training, ATM/ANS and aerodromes organisations) and by the Agency (design and approval of foreign organisations)", from previous EASA outputs [source], [source] and [source];

- The implementation of a regulation structure centred on operations, proportional, risk- and performance-based, for all Open or Specific operations; guaranteeing a high and uniform level of security in operations; fostering the UAV market; contributing to reducing the worries of citizens on security, privacy, data protection and the environment;
- Within the Open category, four subcategories are further defined, from A0 to A3, with A0 and A1 for non-professional operations. Following ECC Report 268 [source, Feb 2018], these are:

i. "A0: 250 g limit, max 15 m/s, max 50 m height";

ii. "A1: Small UAS, heavier than A0, typically up to 4 kg (no explicit limit, limitation is based on kinetic energy impact possibilities), max 50m height, VLOS, controller must be at least at the age of 14. In first-person-view mode or follow-me mode possible;"

iii. "A2: same as A1, but with additional requirements due to higher kinetic energy impact possibility involved, user manual must inform about the obligations of the controller (e.g. to stay at least 50m away from uninvolved persons). Geofencing and electronic identification systems;"

iv. "A3: Comparable to A2 but up to a height of 150m (500 ft) above ground level, unless otherwise determined by the competent authority for the operational area based on airspace considerations (above 150m: Specific category). Competence/training is needed, i.e. examination. Within a range such that the remote pilot, or a UA observer who is situated within the VLOS of the remote pilot, maintains VLOS; clear and effective communication shall be established between the remote pilot and the UA observer; with a minimum horizontal distance of 20 m from uninvolved persons if flying a rotorcraft, or 50 m otherwise."

Slightly different from the above subcategorisation, Figure 3 shows the description of A0-A3 categories, with their relation with UAV classes (privately built, C0 to C4), following EASA's recent keynote [source] and the Opinion No. 01/2018 [source]. For more details on the categories on EASA's, please consult the web brochure [source].

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

Figure 3 - Description and relation between operation subcategories and UAV classes, following EASA's recommendations [source].

In relation to RADAVANT, within the Open category, the primary project's scope will be the professional use under subcategories A2 and A3. Such is also because of the most probable UAV weight, close to or above 4kg (under 25 kg), and the type of deployment scenarios that we are envisaging (inspections and surveying). Most probably, the UAVs where RADAVANT will be installed will fit into C2 to C4 classes, and with flights far from people or close to uninvolved people.

Important Definitions

Within the RADAVANT project, and with such a wide diversified plethora of players and sources, it is ever important to establish a well-defined set of definitions. This will aid in a more effective and structured mindset and better understanding of regulation, within the Consortium and towards the extra-project contexts.

For this, we should point out the useful "Manual on Remotely Piloted Aircraft Systems" [source] and the "Remotely Piloted Aircraft System (RPAS) Concept of Operations (CONOPS) for International IFR Operations" report [source] (IFR, Instrument Flight Rules), from ICAO's Remotely Piloted Aircraft Systems Panel (RPASP) [source]. ITU's Report on "Characteristics of unmanned aircraft systems and spectrum requirements to support their safe operation in non-segregated airspace" Report ITU-R M.2171 (12/2009) [source] is also of important reference. We therefore define the following terms:

- *Beyond Radio Line-of-Sight* (BLOS or BRLOS): a) the indirect radio line between the UAV and the control station, due to resorting to external satellite communication services or other [ITU, source], or [added by the RADAVANT Consortium] due to an obstruction to direct propagation between the UAV and the control station OR b) "refers to any configuration in which the transmitters and receivers are not in RLOS. BRLOS thus includes all satellite systems and possibly any system where an RPS communicates with one or more ground stations via a terrestrial network which cannot complete transmissions in a timeframe comparable to that of an RLOS system." [ICAO, source];

- *Beyond Visual Line-of-Sight* (BVLOS): UAV operation in which neither the pilot or an additional observer have constant visual contact with the UAV, with no visual aid [ICAO, source];
- *Detect And Avoid* (DAA): "the capability to see, sense or detect conflicting traffic or other hazards and take the appropriate action", "appropriate technology and/or procedures may be needed to provide capabilities analogous to those which pilots of manned aircraft have, using one or more senses (e.g. vision, hearing, touch) and associated cognitive processes. The appropriate action is to avoid the hazard (e.g. potentially conflicting traffic) to assure safety objectives for specific airspace or operations are met." [ICAO, source];
- *Hazard*: "an object or condition that has the potential to induce an accident or incident.";
- *Mitigation*: reduction of risks;
- *Non-segregated Airspace*: "airspace other than those designated as segregated airspace." [ITU, source];
- *Radio Line-of-Sight* (LOS or RLOS): a) the direct radio line between the UAV and the control station [ITU, source] OR b) "the situation in which the transmitter(s) and receiver(s) are within mutual radio link coverage and thus able to communicate directly or through a ground network provided that the remote transmitter has RLOS to the RPA and transmissions are completed in a comparable timeframe" [ICAO, source];
- *Segregated airspace*: "Airspace of specified dimensions allocated for exclusive use to a specific user(s)." [ITU, source];
- *Visual Line-of-Sight* (VLOS): UAV operation in which the pilot or an additional observer has constant visual contact with the UAV, with no visual aid [ICAO, source].

In relation to the RADAVANT project and its applications, it is important to be aware of the sort of risks for the planned UAV operation. In order to include such flight operations in the non-segregated airspace, most likely and in most inspection and surveying operations, the RADAVANT radar will work to mitigate such risks. These are [based on ICAO, source]:

- *conflicting traffic*: considered in the TA as *mobile traffic*, airborne or terrestrial, in the vicinity of the UAV. In inspections, this can be the case of other UAVs, planes (though not probable to be of large size), helicopters, trains, cars or trucks. There are very practical real-life situations where such traffic is probable, e.g., the inspection of a road viaduct and the close passage of a large truck, or the inspection of a rail-road and the unexpected approach of a train;
- *terrain and obstacles*: considered in the TA as *fixed obstacles*, e.g., large walls, electric power lines, metal tower masts, tubes;
- *hazardous meteorological conditions*: though not considered in the TA, and although most can be predicted, there is effectively a risk of sudden storms, ice, turbulence, strong wind, heavy rain;
- *ground operations*: considered in the TA as *terrestrial mobile traffic* or *terrestrial fixed obstacles* that may conflict with the take-off and landing;
- *other airborne hazards, including wake turbulence, wind shear, birds or volcanic ash*: some may be out of the scope of RADAVANT, but other are very pertinent, to be considered as *mobile or terrestrial traffic*, e.g., birds or moving cattle.

Scenarios

EASA is currently defining Standard Scenarios (STSs), risk- and process-based [source]. In July 2018, EASA has put forward a workshop on the STSs, showing the joint effort with JARUS for the harmonized definition of such scenarios.These are being prepared to simplify the pilot's implementation and risk mitigation measures:

- In the case of mitigation measures easy to be implemented, the declaration by the UAV operator is sufficient. This should be the "*Standard scenarios under declaration*, where the mitigation measures will be more detailed and applicant will declare that the mitigations and operational safety objectives are met at the level of confidence specified in the standard scenario.";
- If implementation of mitigation measures is more demanding, the authorisation by the NAA will be required, before starting the operation. This shall be the "*Standard scenarios under authorisation*, where the applicant will need to substantiate to the NAA that the mitigations and operational safety objectives are met at the level of confidence specified in the standard scenario.";
- STSs will, for now, apply to the Open and Specific categories;
- The NAA and operator may propose an alternative STS using the "AltMoc process" (AltMoc, Alternative Means of Compliance). There is such openness for the proposal of new STSs. Another possibility is for new STSs to be directly suggested by the EU industry to EASA, possibly fitting into RADAVANT's future contribution to regulation.

During the RADAVANT project, within its prototype tests and demonstrations and in the preparation of a future commercial product (post-project), it is fundamental to keep track of such STSs. This is key in structuring work and objectives, also for the specification phase.

Again, in the context of RADAVANT, we should maintain a critical view on the following practical deployment scenario, and probably even contribute to a new STS:

- In the inspection of a bridge, the UAV operation and the position of the pilot is mostly VLOS;
- But there are two very frequent situations where the UAV is not visually followed: a) the pilot is on the bridge deck and the UAV goes under the bridge deck, or b) pilot and UAV are separated by a pillar, all at very short distances of 10 m;
- Such are BVLOS and BRLOS situations, for which "Minimum equipment requirements to support BVLOS operations increase significantly as the range and complexity of such operations increase, as does the cost involved in ensuring the robustness of the C2 link. The ability to detect conflicting traffic or obstacles and take appropriate action to avoid them is essential." [ICAO, source];
- I.e., even in the short distances, such BVLOS scenario has not been found mentioned or described among the several regulatory bodies. And such is where the RADAVANT radar, as well as the effective use of First Person View (FPV), is absolutely essential, as in the case of long distances.

4.3. RADAVANT and its role for DAA

The RADAVANT Consortium should follow the above category/class guidelines, primarily from EASA, in accordance with several other bodies. Under the wider scope of the RADAVANT project and for the envisaged markets, its deployment should be directed to the Open A2 and A3 subcategories. It should be extended to the Specific and/or Certified categories, due to the nature of the flights, including BVLOS in inspections and surveying, following the risk-centred view. As planned, again, RADAVANT project will keep a close look at such developments.

The rulemaking for UAV flights under the Specific and/or Certified categories has yet to be further created and structured, as well as for BVLOS conditions. In the US context, the project is also following the way that waivers are being submitted and accepted (as well as rejected), to keep track of the BVLOS tendencies for the future [source], or from the FCC's-backed Alliance for System Safety of UAS through Research Excellence (ASSURE) report [source].

Based on such background and on the article "A Review on Collision Avoidance Systems for Unmanned Aerial Vehicles" [source], the project is making its way to further fit its contribution for the future in DAA for UAVs:

- "a collision avoidance system is generally organized into three fundamental functions: the sensing function, the detection function and the resolution function.". RADAVANT will fit into the sensing and detection, aiding in the resolution to be taken by the pilot;
- Radar fulfils its role, regarding range, azimuth, elevation, day and night operation (or lit and in the dark operation), bad weather, for specific deployment scenarios. RADAVANT will be capable of fulfilling these, in the context of the inspection and surveying deployment scenarios;
- RADAVANT will be a non-cooperative passive DAA process, complementary to the transponder and ADS-B cooperative processes. Such perspective of complementary processes for DAA will, undoubtedly, be the solution for safe and cost-efficient UAV drone missions (for VLOS and BVLOS);
- Radar is still generally pointed as a heavy, large and expensive solution. RADAVANT is an excellent opportunity to counteract such wrong view (with SWAP-C, *size weight and power, and cost* benefits). Our close competitors are also very much aware of this.

5. Conclusions

Based on an extensive look at the several Regulations and Regulatory Bodies that should guide our RADAVANT decisions on its radar, data-link and combined DAA functions, the Consortium concludes that:

- RADAVANT's radar block will work in the 24GHz ISM band, for the EU, US and other markets. Since such ISM band is only 250 MHz wide, the consortium shall provide a solution to follow the TA main specifications, namely, concerning the spatio-temporal resolution. There is, anyhow, a potential spectrum use expansion close to 24 GHz band, following the phasing-out of UWB SRR services. RADAVANT's radar implementation will be ready for regulation changes in this band, if required;
- RADAVANT's data-link block will primarily function in the 868 MHz (EU)/915 MHz (US) (shared, unlicensed), 2.4 GHz (shared, unlicensed, also ISM) and 5.8 GHz (shared, unlicensed, also ISM), including operation capabilities that will guarantee the reliability and safety required for professional use. There is, anyhow, a potential spectrum use expansion towards other frequencies close to those, under discussion among many regulatory bodies. RADAVANT's data-link implementation will be ready for regulation changes in this band, if required;
- The RADAVANT Consortium is following the evolution of present and future decisions on these spectrum matters. Undoubtedly, the flexibility of Twevo's Software-Defined-Radio (SDR) technology will be of the utmost importance, in adjusting to such regulation and needs, if required;
- The RADAVANT radar will primarily target the Open A2 and A3 subcategories, as well as C2 to C4 classes, with flights far from people or close to uninvolved people. It should be ready to be extended to the Specific and/or Certified categories (when such regulation arises);
- The RADAVANT project will keep track of the STS, currently in the making. The Consortium will be ready to contribute to these STS, if adequate.