UNICO I+D Project
6G-INTEGRATION-4

E12-6G-INTEGRATION-4

Definition of basic navigation and comms systems for HAPS operation

Abstract

This deliverable contains a definition of required systems for HAPS air traffic integration and basic systems to allow unmanned operations of a LAT (lighter than air) unmanned system into the non segregated airspace. It includes a description of the regulatory framework applicable for the case and definitions of operations as are described by the international authorities in the matter such as ICAO and JARUS. Actually, these authorities do not differentiate between lighter than air and heavier than air aircrafts so, the relevant and applicable regulations for UAS and/or RPAs have been taken into account.

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Reviewers	Eduardo Arca Ramirez (Edair Technologies) Eduardo Cano Corral (Edair Technologies) Daniel Segovia Vargas

SEGOVIA VARGAS DANIEL - 50831780D

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List of Acronyms

ADS-B – Automatic Dependent Surveillance-Broadcast

ARC – Air Risk Class

ATC – Air Traffic Control

ATM – Air Traffic Management

ATS – Air Traffic Services

BLOS – Beyond Line Of Sight

CofA – Certification of Airworthiness

ConOps – Concept of Operations

CPDLC – Controller-Pilot Data Link Communications

DLR - Deutsches Zentrum für Luft- und Raumfahrt (German Center for air- and Space flight)

EASA – European Aviation Safety Agency

ERP - Emergency Response Plan

EU – European Union

FLxxx – Flight Level xxx

GCS – Ground Control Station

GNSS – Global Navigation Satellite Systems

GPS – Global Positioning System

GRC – Ground Risk Class

HAP – High Altitude Platforms

HAPS – High Altitude Pseudo Satellite

ICAO – International Civil Aviation Organization

IFR – Instrument Flight Rules

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ILS – Instrumental Landing System

JARUS – Joint Authorities for Rulemaking of Unmanned Systems

NPA – Notice of Proposed Amendment

OSO – Operational Safety Objectives

PANS - Procedures for Air Navigation Systems

RPA – Remotely Piloted Aircraft

SAIL – Specific Assurance and Integrity Level

SARP - Standards And Recommended Practices

SMS - Safety Management Systems

SORA – Specific Operations Risk Assessment

TMPR – Tactical Mitigation Performance Assurance Requirements

UAS – Unmanned Aerial Systems

UAV – Unmanned Aerial Vehicles

VFR – Visual Flight Rules

VHF – Very High Frequency

VLOS – Visual Line Of Sight

VOR – Very high frequency Omnidirectional Range

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Resumen Ejecutivo

El presente entregable contiene información detallada sobre el marco reglamentario vigente acerca de los sistemas de navegación y comunicaciones necesarios para la operación de un sistema no tripulado como el HAPS que nos ocupa. Incluye definición y desarrollo del concepto de SORA (Specific Operations Risk Assessment) el cual define las necesidades de navegación y comunicaciones del sistema cuya finalidad principal es el control, mitigación y minimización de riesgos inherentes a las operaciones. Se incluyen definiciones de escenarios SORA contemplados en la normativa, un concepto operacional de integración de un sistema HAPS, algunas consideraciones sobre el marco regulatorio ICAO y descripción de sistemas de comunicaciones compatibles.

El resto del documento está redactado en inglés, de cara a maximizar el impacto del trabajo realizado en este proyecto.

Executive Summary

This deliverable contains detailed information on the current regulatory framework regarding the navigation and communications systems required for the operation of an unmanned system such as the HAPS in question. It includes definition and development of the concept of SORA (Specific Operations Risk Assessment) which defines the navigation and communications needs of the system whose main purpose is the control, mitigation and minimization of risks inherent to the operations. It includes definitions of SORA scenarios contemplated in the regulations, an operational concept of integration of a HAPS system, some considerations about the ICAO regulatory framework and a description of compatible communications systems.

The rest of the document is written in English in order to maximize the impact of the work done in this project.

1. Introduction

In recent years, the use of unmanned aerial systems (UAS) for different kinds of operation greatly increased. Primarily operations at low or medium altitudes enjoy great popularity. However, there is an increasing number of applications that require stationary platforms at high altitudes of around 20 km. These High-Altitude Platforms (HAP) are meant to perform operations over a long time period with minimal interactions with regular manned air traffic. HAP operations often include continuous high-altitude observation of a certain area. Some examples of those earth observation operations are cargo ships emission measurements and glacier observations. Such HAPs are in competition with fast low-orbiting satellites. Due to their orbital paths, single satellites always have a delay in time if they are used to observe a specific area. To reduce that delay, several satellites can be used, but this come with the disadvantage of much higher costs.

To cope with UAS and to integrate such systems into the modern air traffic management system, aviation authorities around the world had to introduce a new regulatory framework for unmanned systems. This framework has to take all different kinds of operation into account, both very-low-risk operations, such as small toy drones operated over fields, and operations of larger scale UAS operated over urban areas. This framework has to take all different kinds of operation into account, both very-low-risk operations, such as small toy drones operated over fields, and operations of larger scale UAS operated over urban areas. Therefore, the European Aviation Safety Agency (EASA) introduced three new general categories of UAS operations in 2016 [1]. These three categories are now part of the unmanned civil aviation regulation [2, 3]. The categories address the risk that the different types of UAS operations pose to people on ground and manned air traffic. Operations that pose a minor risk to people, such as the aforementioned toy drones operated over unpopulated areas in visual line of sight (VLOS), are regulated in the 'open' category. Very high-risk operations with a risk comparable to manned aviation, such as large-scale UAS operating over inhabited areas or unmanned transportation of people, are covered in the 'certified' category. All those operations whose risk lies in between the two examples fall into the 'specific' category.

The EASA released a Notice of Proposed Amendment (NPA) as 'Introduction of a regulatory framework for the operation of drones' in 2017 [4] as a form of consultation within the EASA rulemaking process and further introduced measures to mitigate the risk of operations in the 'open' and the 'specific' categories. This NPA was followed by Opinion No 01/2018 [5] that was intended to implement an operation-centric, risk- and performance-based regulatory framework for the 'open' and 'specific' categories. The rulemaking process was finished by the EASA in 2019 with release of the Commission Implementing Regulation (EU) 2019/947 [2] and Commission Delegated Regulation (EU) 2019/945 [3]. Insight in the 'specific' category's regulatory framework and how to apply its safety assessment to UAS operations on the example of HAP operations is provided throughout this document. Furthermore, we present approaches to integrate HAPs into existing Air Traffic Management (ATM) in a safe manner. We also discuss the operational challenges of such long-endurance, high-altitude operations the operator has to face.

With the development of this project, the aim is not only to design a lighter-than-air aircraft capable of providing 5G coverage, but also to ensure that this study is valid and useful. It is essential to understand everything necessary for the aircraft to integrate into airspace, coexisting with existing and future systems.

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Hence, the goal is to define the necessary framework and provide all the steps and documentation required to make the aircraft a secure and reliable system, capable of integration within the framework of global navigation.

The objectives for the aircraft include maintaining continuous flight for 24 hours over an extended period, with technical maintenance stops on the ground. To achieve this, the target altitude will be above the EASA-defined f550 line at 17 km, below which commercial and transport air traffic operates. However, consideration must be given to ascent and descent maneuvers of the High-Altitude Pseudo-Satellite (HAPS), as these instances would fall within this airspace.

The process of obtaining regulations and permits to operate an aircraft lighter than air at 20,000 meters height involves compliance with the regulations and requirements established by the civil aviation authorities of the corresponding country or region.

1. **Identification of Competent Authorities:**
   i. Identify and contact the competent civil aviation authorities in the area where the aircraft is planned to operate. These authorities are responsible for regulating and overseeing air operations.
2. **Analysis of Norms and Regulations:**
   i. Review and understand specific regulations related to the operation of lighter-than-air aircraft at high altitudes. This will include specific regulations for unmanned aerial vehicles (UAVs), balloons, and airships.
3. **Technical and Safety Requirements:**
   i. Ensure that the aircraft complies with the technical and safety standards established by civil aviation authorities. This may include airworthiness certifications and safety assessments.
4. **Submission of Technical Documentation:**
   i. Prepare and submit detailed technical documentation about the aircraft, including specifications, plans, operation and maintenance manuals, and any other documents required by the authorities.
5. **Risk Report and Environmental Impact Assessment:**
   i. Provide detailed reports on the risks associated with operating the aircraft at 20,000 meters altitude, as well as an assessment of potential environmental impacts.
6. **Flight and Operation Plan:**
   i. Submit a flight and operation plan detailing planned activities, flight route, altitudes involved, and any other relevant details. This plan must comply with civil aviation regulations.
7. **Civil Liability Insurance:**
   i. Obtain civil liability insurance that meets the requirements established by the authorities. This insurance should cover potential third-party damages and comply with specified liability limits.
8. **Application and Evaluation Process:**

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   i. Submit a formal application to civil aviation authorities. This application should include all required documentation and follow procedures established by the regulatory entity.

9. **Collaboration and Communication with Authorities:**
   i. Actively collaborate with authorities during the evaluation process. Be prepared to answer questions and provide additional information as necessary.
10. **Review and Approval:**
   i. Allow authorities to review and assess the application. Approval will be granted once it is demonstrated that the operation complies with all regulatory and safety requirements.

It is crucial to emphasise that the process of obtaining regulations and permits may vary by country and specific regulations. Close collaboration with authorities and adherence to established standards is essential to ensure the safety and legality of air operations.

2. Regulatory framework of the 'specific' category

Crucial part of the 'specific' category is the requirement to conduct a risk assessment of the intended UAS operation. A risk assessment methodology that is adopted by the EASA [5] is the Specific Operations Risk Assessment (SORA) developed by the Joint Authorities for Rulemaking of Unmanned Systems (JARUS) [6]. In this section a brief overview of the SORA methodology is given. A more detailed description of SORA and a comparison to an already existing safety assessment approach are given in [7]. The SORA (Fig. 1) is an iterative process to assess the intrinsic risk of a UAS operation, to incorporate risk mitigation strategies and establish the requirements that the operator has to meet to obtain an operation approval of the competent authority. The input to this process is a concept of operations document (ConOps) that contains a description of the intended operation, technical data of the UAS and information on the operator. With the ConOps information, initial Ground and Air Risk Classes are determined. These two classes take the population density and the air traffic density in the operational volume as well as adjacent to it into account. To lower the operational risk, mitigation strategies can be applied. The Ground Risk Class including applied mitigations can range from 0 to 7, while the Air Risk Class range from ARC-a for a-typical airspace to ARC-d for highly frequented airspace such as an airport environment. Ground and Air Risk Class combined with applied mitigation strategies result in a Specific Assurance and Integrity Level (SAIL). Tied to the SAIL are a number of Operational Safety Objectives (OSO), or in other words, requirements the operator has to meet. The OSO shall ensure a safe UAS operation; therefore, they address the technical and design capabilities of the UAS as well as the operator in form of operational, crew training and maintenance requirements. There are six levels with increasing rigor from SAIL I to SAIL VI. The required OSO and the operator's solution to meet them are also an integral part of the ConOps. The complete ConOps has to be submitted to the national competent authority. A detailed description of the SORA process can be found in [6].

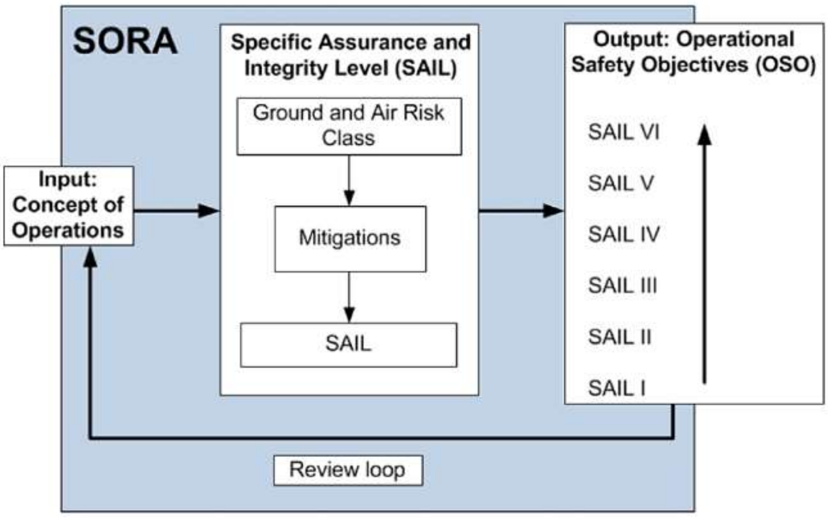

Figure 2-1. Simplified SORA process modified from [8]

This report provides a detailed guide on the certification requirements for a self-manufactured Lighter-Than-Air Unmanned Aerial Vehicle (UAV), with the goal of operating in both non-segregated and segregated airspace within the European Union (EU). The certification process focuses on compliance

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with safety and performance standards set by the European Union Aviation Safety Agency (EASA) and national aviation authorities.

1. **UAV Design and Documentation:**
    a. Detailed description of the UAV design.
    b. Plans and technical specifications.
    c. Documentation on materials used.
    d. Operation and maintenance manuals.
2. **Design and Risk Assessment:**
    a. a) Collaboration with design and safety experts to assess risks associated with the UAV design.
    b. b) Identification and mitigation strategies for potential failure modes and effects.
3. **Certification of Airworthiness (CofA):**
    a. Collaboration with EASA to obtain Type Certification (Letter of Intent and Type Certification (TC) application).
    b. Validation of specific airworthiness for the self-manufactured UAV.
    c. Demonstration of compliance with safety and performance standards.
4. **Airspace Assessment:**
    a. Analysis of EASA regulations and national authorities for operating in both non-segregated and segregated airspace.
    b. Development of a flight plan complying with authority requirements.
        i. Flight plan for non-segregated airspace.
        ii. Flight plan for segregated airspace.
    c. Compliance Report (Detailed document demonstrating compliance with EASA and national regulations).
5. **Pilots and Operators Certification:**
    a. Training and certification of pilots and operators as per national authority requirements.
    b. Demonstration of specific skills and knowledge to operate the UAV.
6. **Civil Liability Insurance:**
    a. Obtain civil liability insurance complying with EASA and national authority requirements.
    b. Adequate coverage for potential third-party damages.
7. **Ongoing Commitment to Safety:**
    a. Implementation of a continuous evaluation and maintenance plan to ensure safety throughout the UAV's lifecycle.
    b. Record and documentation of modifications and updates made.

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3. Use case scenarios and SORA analysis

In this section, some typical use cases for HAPs are described and analyzed with the SORA process in its latest edition [6]. The use cases are chosen to show the spectrum of possible HAP operations from a regulatory and operational effort point of view. In case of the SORA analysis the mission examples can be classified by their initial ground risk. The SORA distinguishes the HAP-relevant scenarios to determine the initial ground risk class in flights beyond visual line of sight (BVLOS) in sparsely populated environments and in populated environments. Until now, there is no explanation provided by JARUS when to consider a sparsely populated and when a populated environment. It is plausible to assume that each national civil aviation authority has its own definition of sparsely and populated environment. However, regarding the possible operational areas shown in Fig. 2 and considering the operational altitude of a HAP, some assumptions can be made. It is relatively safe to assume that glaciers and snow surfaces observation, Northeast Passage icing observation, maritime surveillance over the Mediterranean Sea and animal tracking in South Africa will be considered sparsely populated. Flood and earthquake monitoring in Central or Southern Europe will be most likely considered populated. The ship emissions observation operation is planned to take place over the English Channel. While the sea itself might be considered sparsely populated, taking the HAP altitude of 20 km and the seaports of the relatively small English Channel into account, the operational area might have a populated environment rating.

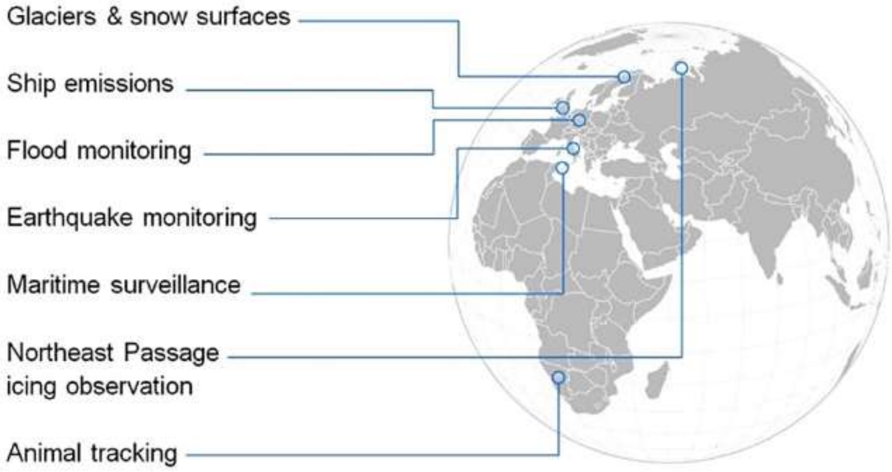

Figure 3-1. Mission examples for HAP operations

As a small summary, the classification of the HAP use case operations regarding their initial ground risk class (GRC) according to the SORA is shown in Table 1. This class takes the HAP's characteristic dimension of over 8 m into account. Within the SORA, it is essential to know that only operations with a GRC of less than seven are covered by this assessment. Operations with a GRC of more than seven are considered to be too dangerous and should not be performed in the 'specific' category. However, it is possible to reduce the initial GRC by means of mitigation. The SORA introduces three possible forms of mitigation that reduce the GRC when applied. The amount of reduction is defined by the integrity of a mitigation and its assurance. Integrity and assurance are combined in the term robustness. Within SORA there exist three levels of robustness: low, medium and high. A low level of assurance is typically achieved by declaration, a medium level of assurance is achieved by supporting evidence such as analyses and simulations and a high level of assurance requires competent third-party verification. Table 2 shows applicable mitigations and their effects on the GRC.

HAP use case operation	Initial GRC
Glaciers and snow surfaces observation	6
Maritime surveillance	6
Northeast passage icing observation	6
Animal tracking	6
Ship emissions over the english channel	10
Flood and earthquake monitoring	10

Table 3-1. Initial GRC classification of HAP use case operations

Mitigations to reduce the GRC	Robustness		
	Low	Medium	High
M1—strategic mitigations for ground risk	0 None − 1 Low	− 2	− 4
M2—effects of ground impact are reduced	0	− 1	− 2
M3—an Emergency Response Plan (ERP) is in place, operator validated and effective	1	0	− 1

Table 3-2. Mitigations to reduce the GRC

M1 is a mitigation where an area around the area of operation is used to reduce the number of people at risk when the UAS leaves the operational volume. Within SORA this certain area is called ground risk buffer. The operator has to verify that the number of people at risk inside the ground risk buffer is less than in the buffer's surrounding area, e.g. by means of population density maps. Depending on how much credit for the buffer shall be taken to reduce the ground risk, the buffer has to follow at least a 1-to-1 rule, meaning the buffer size depends on the UAS altitude. If the lowest requirement for the ground risk buffer is applied to a HAP, a flight altitude of 20 km would result in a ground risk buffer of 20 km around the area of operation. On higher robustness classes, starting at medium robustness, the buffer has to take weather conditions, aircraft performance such as the glide ratio and the occurrences of single failures, which would lead to operation outside of the operational volume, into account. M2 shall significantly reduce the impact energy up to a level where it can be reasonably assumed that a fatality will not occur. This can be achieved by the use of additional equipment or by strategy, such as an emergency parachute. M3 is an emergency response plan that shall limit the escalating effects of a UAS crash and define conditions to alert the responsible ATM. It shall handle situations where the operation is out of control. It is up to the operator to decide if one or more mitigations are used to reduce the initial ground risk. However, when applied the mitigations must comply with the requirements given by SORA, depending on the level of robustness. As an example in case of a HAP, the DLR aims for a low M1 robustness and a medium M2 and M3 robustness. The specific requirements to be able to claim low and medium robustness for M1 and M2 are shown in Annex B of the SORA Guidelines. Since this document is focusing on the operational part of a HAP system, the mitigation of interest is M3. The requirements to claim medium robustness for M3 are that the ERP

- Is suitable for the situation
- Limits the escalating effects
- Defines criteria to identify an emergency situation
- Clearly delineates remote crew member(s) duties

To assure the effectiveness of the ERP it

- Is developed to standards considered adequate by the competent authority and/or in accordance with means of compliance acceptable to that authority
- Is validated through a representative table top exercise consistent with the ERP training syllabus
- A record of the ERP training completed by the relevant staff is established and the record is kept up to date

Applying all those mitigations (M1–M3) will lower the initial GRC to 4 in case of operations over sparsely populated environments and to 8 in case of populated environments. A final GRC of 8 means that this operation cannot be performed in the ‘specific’ category. For operations with a final GRC of 8 either mitigations with a higher robustness have to be applied or the operator has to rely on a special permit. This might be the case after catastrophic events such as earthquakes where the country’s authority might wish to use a HAP to help save human lives. After the ground risk branch is completed, the air risk class (ARC) has to be determined. In general, the initial air risk class depends on the air traffic density to be expected in the operational volume, respectively the expected encounter rate with manned aircraft. The aircraft encounter rate is based on the ICAO airspace classification. The air risk class ranges from ARC-a for an atypical airspace with an encounter rate of 10−6 per flight hour up to ARC-d for controlled civil airspace 500 ft above ground level. For the overall ARC determination, the operation’s highest ARC rating has to be considered. The ARC rating then has impact on the SAIL and additionally on “tactical mitigations” which are ARC-driven air risk-specific requirements for the aircraft and the operator. Annex D of the JARUS guidelines on SORA shows the specific performance requirements of the tactical mitigations for all air risk classes. The tactical mitigation performance assurance requirements (TMPR) vary from no requirements at all for ARC-a up to high requirements, which are based on aviation standards, for ARC-d. The integrity requirements of the general system that performs the tactical mitigations, called Tactical Mitigation System in SORA terms, range from less than one loss per 100 flight hours for ARC-a to less than one loss per 100,000 flight hours for ARC-d (Table 3). Within the SORA process, the general ARC rating for very-high-altitude flights above flight level 600, around 18 km, is ARC-b. However, a HAP will ascend and descend at least once right through all airspace categories from ground level to the HAP’s cruise altitude above the civil airspace. Therefore, the highest air risk class, ARC-d, applies for any HAP operation as initial ARC. Similar to the ground risk classification, the operator is allowed to use the so-called “strategic mitigations”. To reduce the initial ARC, the operator is allowed to show that the actual encounter rate within the operational volume is less than the general classification and/or the time of exposure in a certain high-density airspace class is very low to justify a lower residual ARC. Table 3 shows that it is always beneficial to try to reduce the initial ARC to ARC-b at least. The TMPR and qualitative criteria shown in Annex D of the JARUS Guidelines on SORA for ARC-b are much easier to achieve and to prove, compared to the other ARC TMPR requirements.

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In the HAP use case scenarios, there are two occasions where ARC-b does not initially apply. Ascent and descent will be through all airspace classes and additionally the HAP will descend to 15.5 km at night time and, therefore, operates within controlled civil airspace. Potential strategic mitigations and operational concepts as an argument for an ARC-b or even ARC-a rating are given in chapter 4. For the purpose of this document, it is assumed that these strategic mitigations will result in an overall ARC-b. The reasoning for the ARC reduction is described in Sect. 4. The resulting SAIL is determined by the combination of GRC and ARC. However, it is the higher risk class that establishes the resulting SAIL. The interaction between GRC rating and residual ARC resulting in a SAIL classification can be seen in Table 4. The final GRC of 4 for the BVLOS operations in sparsely populated environments together with the assumed ARC-b result in SAIL III. As shown in Fig. 1, the SAIL expresses how each of the 24 operational safety objectives (OSO) required by the SORA has to be fulfilled. All OSO are described in Annex E of the JARUS guidelines on SORA. The following chapter discusses an operational concept to integrate a HAP system in civil airspace and as mentioned above, the necessary reasoning for an air risk reduction to ARC-b level.

TMPR: N/A (ARC-a)	TMPR: low (ARC-b)	TMPR: medium (ARC-c)	TMPR: high (ARC-d)
Allowable loss of function and performance of the Tactical Mitigation System: <1 per 100 flight hours (10^{-2} Loss/fh)	Allowable loss of function and performance of the Tactical Mitigation System: <1 per 100 flight hours (10^{-2} Loss/fh)	Allowable loss of function and performance of the Tactical Mitigation System: <1 per 1,000 flight hours (10^{-3} Loss/fh)	Allowable loss of function and performance of the Tactical Mitigation System: <1 per 100,000 flight hours (10^{-5} Loss/fh)
No assurance required	The operator is declaring that the Tactical Mitigation System and planned procedures will mitigate the risk of collisions with manned aircraft to an acceptable level	The operator provides evidence that the Tactical Mitigation System will mitigate the risk of collisions with manned aircraft to an acceptable level	The evidence that the Tactical Mitigation System will mitigate the risk of collisions with manned aircraft to an acceptable level is verified by a competent third party

Table 3-3. Tactical mitigation performance requirements

SAIL determination				
Final GRC	Residual ARC			
	a	b	c	d
≤ 2	I	II	IV	VI
3	II	II	IV	VI
4	III	III	IV	VI
5	IV	IV	IV	VI
6	V	V	V	VI
7	VI	VI	VI	VI
>7	Out of scope of SORA			

Table 3-4. SAIL determination.

This report outlines the steps and necessary documentation for conducting a Safety Risk Assessment (SORA) on a self-manufactured Lighter-Than-Air Unmanned Aerial Vehicle (UAV). The SORA is conducted with the objective of operating in both non-segregated and segregated airspace within the European Union (EU). The focus is on compliance with safety standards and regulations established by the European Union Aviation Safety Agency (EASA) and national authorities.

1) **System Identification and Operational Context:**

   a) UAV Description
   b) Operational Areas (Detailed description of areas where operations are planned)
2) **Concept of Operations (CONOPS) Development:**
   a) Flight Plan:
      i) Flight Plan for Non-Segregated Airspace: [Details on planned route and altitude.]
      ii) Flight Plan for Segregated Airspace: [Specific plan for operations in segregated airspace.]
   b) Integration with Air Traffic:
      i) Strategies for integration with other aircraft and air traffic activities.
3) **Risk Assessment:**
   a) Risk Identification:
      i) Detailed analysis of potential risks during operations.
   b) Risk Assessment:
      i) Evaluation of the probability and impact of each identified risk.
   c) Risk Mitigation:
      i) Strategies and actions to reduce or eliminate risks.
4) **SORA Documentation:**
   a) Risk Assessment Report:
      i) Details on the methodology used and results obtained.
      ii) Detailed evaluation of each identified risk.
      iii) Risk Matrix: Table showing the probability and impact of each risk.
   b) Risk and Mitigation Registry:
      i) Detailed document listing all identified risks, their assessments, and proposed mitigation measures.
      ii) Each risk should have a unique identification number.
      iii) Clear description of mitigation measures and how they will be implemented.
5) **Consultation with Authorities:**
   a) Review by EASA and National Authorities:
      i) Letter of Intent: [Official letter expressing the intention to undergo review by EASA and national authorities.]
      ii) Submission of the SORA Report.
      iii) Responses to comments or requests for additional information.
6) **Additional Safety Requirements:**
   a) Implementation of Security Measures:
      i) Specific actions to comply with additional safety requirements identified during the SORA.
      ii) Implementation Plan: Document detailing how additional security measures will be implemented.
      iii) Compliance Certificates: Documents demonstrating that security measures have been implemented as planned.
7) **Ongoing Commitment to Safety:**
   a) Monitoring and Updates:
      i) Procedures for continuous monitoring of safety and updates as necessary.

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The successful completion of a Safety Operation Risk Assessment (SORA) for a self-manufactured lighter-than-air UAV, intended to operate in both non-segregated and segregated airspace, requires a detailed understanding of risks and the implementation of mitigation measures. This report provides a comprehensive guide to conduct an effective SORA and comply with safety standards set by EASA and national authorities.

All these steps are necessary to ensure that the aircraft passes all necessary checks for its aerial activity. Emphasizing the ultimate goal, the regulatory framework for pseudo-satellite platforms above the f550 flight band is still under evaluation by EASA. The processes and steps taken by EASA to establish this regulatory framework have been compiled in this report.

4. Operational concept to integrate a HAP system into civil airspace regarding the SORA requirements

Strategic mitigation measures reducing the ARC have to be categorized along the flight phases. A distinction is made between climb, cruise and descent.
To be able to reduce the risk level during the climb and descent phases, separation from the rest of the traffic is assumed for this part of the flight. This means that these flight phases are carried out within restricted airspaces. It should be noted that such measures reduce the specific risk, but that the establishment or activation of appropriate flight restriction areas, depending on the traffic load at the planned flight location, results in an impairment of air traffic. In addition to the location of the restricted area, its spatial characteristics and the duration of the required activation are decisive for the magnitude of the impact. It must, therefore, be the aim to keep these effects as low as possible while at the same time fulfilling the safety requirements.
During mission flight as well as in special transfer flight phases, the HAP concept considered here assumes the use of an altitude range between 15.5 km and about 25 km. A descent below 20 km during the night will be performed to save electrical energy by the use of its potential energy. This corresponds with entering ICAO class A or C airspaces.
For class A airspaces, only Instrument Flight Rules (IFR) flights are permitted. All flights are provided with air traffic control service and are separated from each other. Class C airspace permits Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) flights, all flights are provided with air traffic control service and IFR flights are separated from other IFR flights and from VFR flights. VFR flights are separated from IFR flights and receive traffic information in respect of other VFR flights [9].
When a HAP has to descend to ICAO class A or class C airspaces, it has to comply with either IFR or VFR. However, it is obvious that a UAS cannot fly under VFR and IFR addressing UAS have yet to be developed. Nevertheless, focusing only on existing minimum equipment lists for IFR even they become quite a challenge for HAP. Main reason is the aircraft's limited mass budget because of the very high operational altitude among other limiting factors such as available solar energy and battery technology. Considering especially the general operational concept of an unmanned HAP, for practical reasons carrying certain equipment elements does not seem to make sense, e.g. the integration of a Very-High-Frequency Omni-Directional Range (VOR) radio navigation system, Instrument Landing System (ILS) and other navigation systems required on manned civil aircraft. Another prerequisite is the ability to communicate directly with air traffic control (ATC) via Very-High-Frequency (VHF) radio. Usually, redundant VHF devices are provided for this purpose. Deviating from this requirement, alternative

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solutions would seem to make sense in which only one VHF device is integrated and a telephone connection to the controller is set up as a second communication channel. Following this approach the situational awareness of the ATC could be held on an equal level without coming into conflict with the initial purpose of the redundant ATC communication. This approach also assumes that the remote pilot is in contact with the ATC at any time during the HAP mission. Even if HAP long endurance missions are heavily automated, we expect that a remote pilot has to be aware of the HAP current status and its environment. Considering necessary shift work it seems plausible to have ATC communication availability comparable to civil manned aviation. This might be possible if operating procedures have been agreed with the relevant national authorities in the near future in favor of our approach to make it possible to dispense with a further on-board radio system.

For the time the HAP flies in an altitude range above 20 km or FL600 (depending on the definition of the upper airspace limit; in some states above 22 km or FL660), it operates within a zone without clearly defined regulations. This altitude zone above 20 km is addressed as “Higher Airspace”, or “Near Space”—depending on whether it is seen from the aviation or space domain. Although controlled airspace in most states is defined up to an altitude of 20 km (FL600) or 22 km (FL660), technically the sovereignty of states over their airspace does not end there. As there is no defined delimitation of air and space, higher airspace theoretically stretches up to very high altitudes and currently represents a region of ambiguous regulation.

This near space is seeing increased interest not only by HAP but also by the expansion of commercial space flight activities (including suborbital flights) and the emergence of new high-speed concepts for passenger transport. The variety of potential operating modes represents a particular challenge, as the higher airspace will get populated by very different users who might want to persistently stay or transit vertically and horizontally through it at vastly different speeds.

Despite this expected development, however, it can be assumed at the present time that only a low volume of air traffic prevails in altitudes above 15.5 km. The operational altitude of some business jets reaches up to this altitude limit, airliners fly up to a maximum altitude of just under 14 km. Larger altitudes have so far been used primarily by military aircraft. Military aircraft in high altitudes could be a problem considering limited detectability. To avoid possible conflicts, care must be taken to ensure that at least the HAP can be detected with sufficient reliability, e.g. by the transponder carried and by ATC awareness. Even if ATC is not directly available in some cases, information that a HAP is going to operate in high altitudes useful to reduce conflict potential with military aircraft. To sum it up, the overall low volume of traffic in the operational altitude band should make a significant contribution to reducing the ARC.

An aspect not covered by the SORA ARC is the case of emergency descents into lower airspaces that may become necessary due to system failures. There are at least two points that need to be considered here. Even without a type certification, a fully operable HAP has to be developed with a strong focus on reliability. Long-endurance operations require hundreds and thousands of continuous operating hours without any maintenance. As an example, a long endurance operation of 100 days will add 2400 flight hours without maintenance to the HAP. To be able to survive such a mission with a decent likelihood, the HAP aircraft needs to have a failure rate of at least 10^{-4} per flight hour or even less. That is not quite civil manned aviation standard but it is not a bad reliability either. The second point that needs to be considered is the emergency descent procedure. This procedure is strongly linked to manned aviation. The key factors are situational awareness of the pilots and ATC communication. In manned aviation, the pilot will have to detect the failure or the source of the problem at least and then inform the ATC about the emergency descent he has to perform. The handling in case of a HAP can be quite similar. We proclaimed before that the remote pilot and the remote crew as a whole need to have awareness of the aircrafts status and environment at any time during the mission. This awareness shall also include detection of behavior that requires an emergency descent. The ATC will be informed

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of the emergency together with additional information on, for example, altitude as well as heading and expected descent corridor.

5. Some considerations about ICAO Regulatory Framework regarding UAS and RPAS operations

5.1. GENERAL CONCEPT OF OPERATIONS

UAS will operate in accordance with ICAO Standards that exist for manned aircraft as well as any special and specific standards that address the operational, legal and safety differences between manned and unmanned aircraft operations. In order for UAS to integrate into non-segregated airspace and at non-segregated aerodromes, there shall be a pilot responsible for the UAS operation. Pilots may utilize equipment such as an autopilot to assist in the performance of their duties; however, under no circumstances will the pilot responsibility be replaced by technologies in the foreseeable future.

To better reflect the status of these aircraft as being piloted, the term "remotely-piloted aircraft" (RPA) is being introduced into the lexicon. An RPA is an aircraft piloted by a licensed "remote pilot" situated at a "remote pilot station" located external to the aircraft (i.e. ground, ship, another aircraft, space) who monitors the aircraft at all times and can respond to instructions issued by ATC, communicates via voice or data link as appropriate to the airspace or operation, and has direct responsibility for the safe conduct of the aircraft throughout its flight. An RPA may possess various types of auto-pilot technology but at any time the remote pilot can intervene in the management of the flight. This equates to the ability of the pilot of a manned aircraft being flown by its auto flight system to take prompt control of the aircraft.

RPA is a subset of unmanned aircraft. Throughout this document, "unmanned aircraft" or "unmanned aircraft system" will be used as all-encompassing terms, whereas "remotely-piloted aircraft" or iterations thereof will refer only to the piloted subset.

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5.2. RULES OF THE AIR

Annex 2 — Rules of the Air constitutes Standards relating to the flight and maneuvers of aircraft within the meaning of Article 12 of the Chicago Convention. Over the high seas, therefore, these Standards apply without exception. In addition, Annex 2 is applicable to aircraft bearing the nationality and registration marks of a contracting State, wherever they may be, to the extent that the marks do not conflict with the rules published by the State having jurisdiction over the territory overflown.

5.3. COLLISION AVOIDANCE

The pilot-in-command of a manned aircraft is responsible for detecting and avoiding potential collisions and other hazards (see Figure 5-1). The same requirement will exist for the remote pilot of an RPA. Technology to provide the remote pilot with sufficient knowledge of the aircraft's environment to fulfil the responsibility must be incorporated into the aircraft with counterpart components located at the remote pilot station.

As stated in Annex 2, paragraph 3.2:

Note 1.— It is important that vigilance for the purpose of detecting potential collisions be exercised on board an aircraft, regardless of the type of flight or the class of airspace in which the aircraft is operating, and while operating on the movement area of an aerodrome

Aircraft pilots are required to observe, interpret and heed a diverse range of visual signals intended to attract their attention and/or convey information. Such signals can range from lights and pyrotechnic signals for aerodrome traffic to signals used by intercepting aircraft. Remote pilots will be subject to the same requirements despite not being on board the aircraft, necessitating development and approval of alternate means of compliance with this requirement.

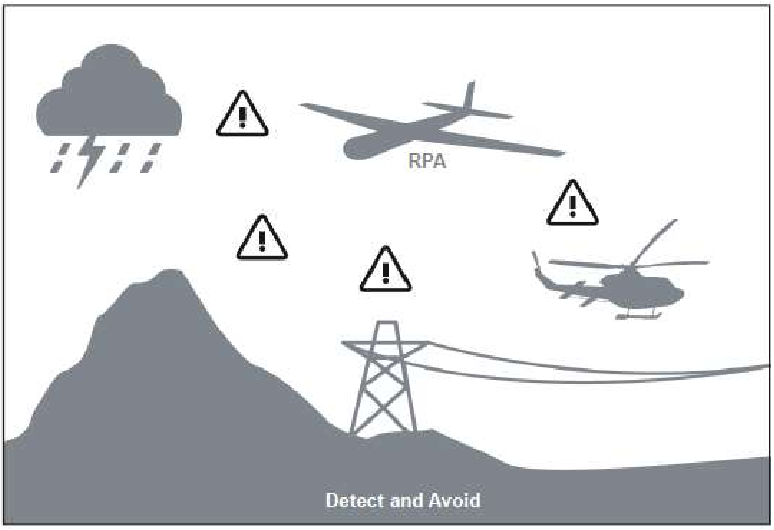

Figure 5-1. Detect and Avoid

Considering each of the above, RPAS detect and avoid solutions will be required to meet specified performance requirements related to flight crew responsibilities. Both the aircraft and the remote pilot station will need to incorporate aspects of this functionality to achieve the complete technical solution required as part of the RPA operational approval. Depending on the type and location of the operations the RPA will conduct, these could include the ability to:

a) Recognize and understand aerodrome signs, markings and lighting;
b) Recognize visual signals (e.g. interception);
c) Identify and avoid terrain;
d) Identify and avoid severe weather;
e) Maintain applicable distance from cloud;
f) Provide “visual” separation from other aircraft or vehicles; and
g) Avoid collisions.

5.4. AIR TRAFFIC SERVICES

Annex 11 — Air Traffic Services relates to the establishment of airspace, ATS units and services necessary to promote a safe, orderly and expeditious flow of air traffic which, together with Annex 2, is intended to ensure that flying on international air routes is carried out under uniform conditions designed to improve the safety and efficiency of air operation.

For RPA, the following specificities need to be addressed:

a) ATM provisions may need to be amended to accommodate RPA, taking into account unique operational characteristics of the many aircraft types and sizes as well as their automation and nontraditional IFR/VFR capabilities; and

b) Air navigation service providers will need to review emergency and contingency procedures to take account of unique RPA failure modes such as C2 link failure, parachute emergency descents and flight termination

5.5. EQUIPMENT

All applicable equipment mandated in the Annexes, both for airworthiness and for operation, will be required for the RPAS, either directly or through an alternative (e.g. a digital compass instead of a magnetic compass).
The difference will be that the equipment will be distributed over the RPA and remote pilot station. In addition to the equipment already required, there will be new equipment introduced to allow the RPAS to operate as a system. This may include, but is not limited to:

a) Detect and avoid technologies; and

b) Command and control systems to provide the connection between the RPA and remote pilot station.

5.6. ATS/REMOTE PILOT COMMUNICATIONS

ATS/remote pilot communication requirements must be assessed in the context of an ATM function, taking into account human interactions, procedures and environmental characteristics. An SMS approach should be employed to determine the adequacy of any communications solutions.

Current telecommunication procedures ensure voice and data messages are composed in a standardized format for both air-to-ground and ground-to-ground communications. For RPA, communications procedures will likely be based upon current practices applicable in the airspace classes in which the RPA operates.

Any requirements on type and level of interaction RPA must be capable of achieving with other users and service providers will need to be fully addressed prior to RPA integrating with manned aircraft. Topics such as situational awareness will require a deeper understanding of RPA's benefits and problems. Benefits that have been coincidentally achieved within manned aviation will need to be specifically charted for RPAS as they may not be automatically available in future designs (e.g. remote access to electronic aeronautical information). In addition, other new ATS features such as 4-dimentional trajectories must be reviewed for RPA use and adoption.

As with manned aviation, current communication technologies for RPA must continue to be supported with clear and proven procedures. Novel techniques may need to be employed to support the use of current technologies for ATS/remote pilot communications. Several technical solutions are available, however it will be vital that any such solution which is not the norm for the particular ATS unit will have been approved by the ATS authority prior to the flight/operation. (See Figure 5-2.) Essential considerations include but may not be limited to volume of traffic, type and location of operation, ease of access to the communications method and its reliability.

Technical and operational interoperability with manned aircraft must be maintained. A prerequisite for this is compliance with the provisions of Annex 10 — *Aeronautical Telecommunications*, Volume II — *Communication Procedures including those with PANS status*. In the case of RPAS, the provisions dealing with loss of communication will most likely require special technical solutions.

Transaction time. The air-to-ground communication links may prove to be inadequate if there are substantial transmission delays between ATC and the remote pilot. This may have implications for future technological solutions to be used for direct controller/pilot communications.

The traditional requirement for a pilot to monitor an assigned ATC frequency channel for analogue radiotelephony must be assessed. Aside from the obvious need to respond to ATC, there is a collateral benefit in that pilots gain situational awareness by listening to the voice traffic, particularly regarding the intentions and positions of other aircraft.

Phraseology. To increase the situational awareness of air traffic controllers and other pilots on the frequency, remote pilots may be directed to prefix their call signs with "remotely-piloted" or something similar, possibly only on the first call, during voice communications between ATC and the remote pilot station.

Technical protocols and operational procedures will be required to support the handover of piloting functionality between the remote pilot stations. The aircraft must be under the piloting control of only one remote pilot station at a time. The system should be capable of supporting the automatic transfer of C2 data link authority between designated remote pilot stations using digital data interchange. Remote crew procedures would verify the link and ensure the "relief" crew briefing was complete prior to terminating the C2 data link with the transferring remote pilot station. An analogy exists with controller-pilot data link communications (CPDLC) in the technical protocols used for transferring data link authority from one ATC facility to another as an aircraft approaches a transfer-of-control point.

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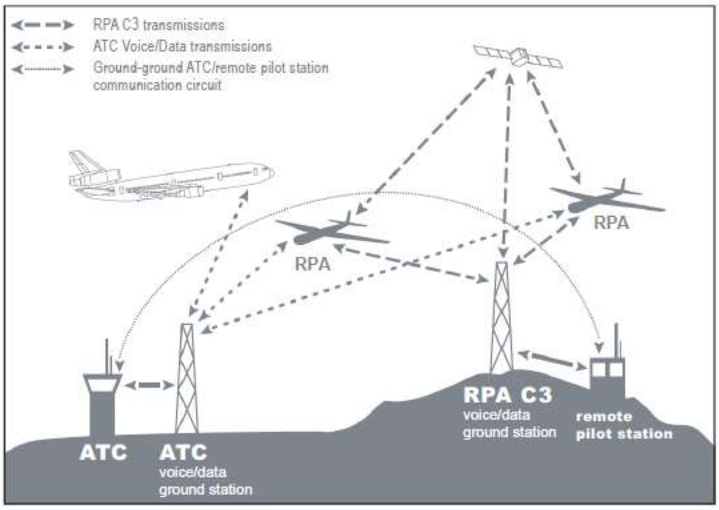

Figure 5-2. Communication links

5.7. AERODROMES

It is generally recognized that integration of RPA into aerodrome operations will prove to be among the greatest challenges. At issue are provisions for the remote pilot to identify, in real-time, the physical layout of the aerodrome and associated equipment such as aerodrome lighting and markings so as to manoeuvre the aircraft safely and correctly. RPA must be able to work within existing aerodrome parameters. Aerodrome standards should not be significantly changed, and the equipment developed for RPA must be able to comply with existing provisions to the greatest extent practicable. Moreover, where RPA are operated alongside manned aircraft, there needs to be harmonization in the provision of ATS.

Consideration may be given to the creation of airports that would support RPAS operations only. Current provisions regarding aerodrome design, construction and operations would continue to apply, however some amendments or additions may be necessary to accommodate unique RPAS issues.

Annex 14 sets forth the minimum SARPs that prescribe the physical characteristics and obstacle limitation surfaces to be provided for at aerodromes, and certain facilities and technical services normally provided. It is not intended that these specifications limit or regulate the operation of an aircraft. The Annex does provide for the accommodation of current types of manned aircraft and, therefore, should equally address the same or comparable types of RPA. However, changes may be necessary to the Annex should unique issues arise that cannot be addressed with the current provisions.

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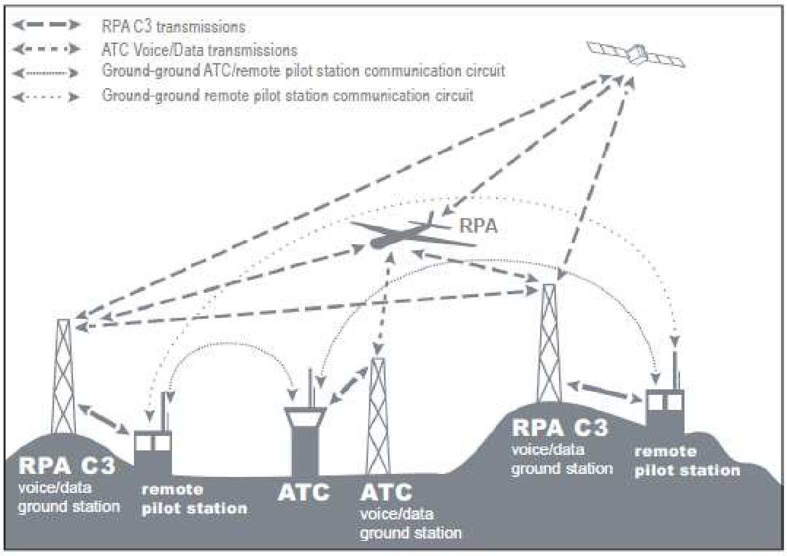

Figure 5-3. Communication links

The unique characteristics of RPA that would affect aerodrome operations will need to be considered to facilitate the integration of these aircraft. Some of the areas to be considered are:

a) Applicability of aerodrome signs and markings for RPA.

b) Integration of RPA with manned aircraft operations on the manoeuvring area of an aerodrome.

c) Issues surrounding the ability of RPA to avoid collisions while manoeuvring.

d) Issues surrounding the ability of RPA to follow ATC instructions in the air or on the manoeuvring area (e.g. "follow green Cessna 172" or "cross behind the Air France A320");

e) Applicability of instrument approach minima to RPA operations.

f) Necessity of RPA observers at aerodromes to assist the remote pilot with collision avoidance requirements.

g) Implications for aerodrome licensing requirements of RPA infrastructure, such as approach aids, ground handling vehicles, landing aids launch/recovery aids, etc.

h) Rescue and firefighting requirements for RPA (and remote pilot station, if applicable).

i) RPA launch/recovery at sites other than aerodromes.

j) Integration of RPA with manned aircraft in the vicinity of an aerodrome; and

k) Aerodrome implications for RPA-specific equipment (e.g. remote pilot stations).

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6. Comms systems applied to selected autopilot

This section will detail various systems necessary for system communications through the autopilot. This component could be defined as the brain of the aircraft at the navigability level, since it is from this component that the control of the systems that make up the vehicle is performed. The autopilot can constitute from a system in charge of transforming the commands given by an operator, to the control of the totally autonomous aircraft, based on the readings of the sensors about the surrounding conditions.

6.1. GNSS

GNSS stands for Global Navigation Satellite System. It is a satellite-based navigation system that provides accurate positioning and timing information to users anywhere on or near the Earth. The primary purpose of GNSS is to determine the precise location of a user's receiver device, such as a GPS receiver, in terms of latitude, longitude, and altitude.

Key components of GNSS include:

Satellite Constellation:

- A network of satellites orbiting the Earth forms the GNSS constellation. The most well-known system is the Global Positioning System (GPS), which is operated by the United States. Other GNSS systems include GLONASS (Russia), Galileo (European Union), BeiDou (China), and NavIC (India).

Ground Control Segment:

- Ground control stations on Earth monitor and manage the satellites in the GNSS constellation. They ensure that the satellites are functioning correctly and provide updates to their orbital parameters.

User Receivers:

- GNSS receivers, commonly found in devices like smartphones, cars, aircraft, and surveying equipment, receive signals from multiple satellites. These receivers use the signals to calculate the user's precise position and track their movement.

Satellite Signals:

- The satellites broadcast signals that include information about their location and the time the signal was transmitted. The GNSS receiver uses these signals to triangulate its position.

The most widely used GNSS is the Global Positioning System (GPS), which was developed and is maintained by the United States Department of Defense. Other GNSS systems, as mentioned earlier, are operated by different countries and regions.

GNSS has become an essential technology for various applications, including navigation for vehicles, aircraft, and ships, precise timing for communication networks, surveying and mapping, and location-

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based services on smartphones. It plays a crucial role in modern navigation and positioning systems, offering global coverage and high accuracy.

6.2. ADS-B

ADS-B, or "Automatic Dependent Surveillance-Broadcast," is an automatic surveillance system that enables aircraft to determine their position using satellite navigation and then automatically transmit this information periodically to other aircraft and ground stations. This technology is pivotal in the modernization of air traffic management systems and serves various purposes:

Aircraft Tracking:

- Aircraft equipped with ADS-B transmit precise information about their position, altitude, speed, and other relevant data. This allows other aircraft and ground stations to know the real-time location of each aircraft.

Enhancement of Situational Awareness:

- Both pilots and air traffic controllers can use the information provided by ADS-B to enhance their situational awareness, contributing to more efficient and safe air traffic management.

Collision Avoidance:

- By knowing the position and trajectory of other nearby aircraft, pilots can make informed decisions to avoid collisions and improve operational safety.

Optimization of Airspace:

- ADS-B systems enable more efficient airspace management by providing precise information about aircraft locations, facilitating route planning, and reducing traffic conflicts.

Secondary Radar Replacement:

- ADS-B is considered a technology that can replace or complement secondary radar systems for aircraft tracking. It offers broader and more accurate coverage, especially in remote areas.

Applications in General Aviation and Drones:

- In addition to its use in commercial aviation, ADS-B is also being implemented in general aviation and traffic management systems for drones. This contributes to the safe integration of unmanned aircraft into airspace.

In summary, ADS-B is a critical technology for improving safety and efficiency in air traffic management by providing a clear and real-time view of the location and movement of aircraft.

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6.3. Veronte Communication Layouts

In this section, different communications layouts are presented. They are based on a Veronte 1x solution, but all of them could be used with any other autopilot depending on which communications devices are used. The main goal of this report is to show a series of graphics that encapsulates different approaches that could be used in different situations.

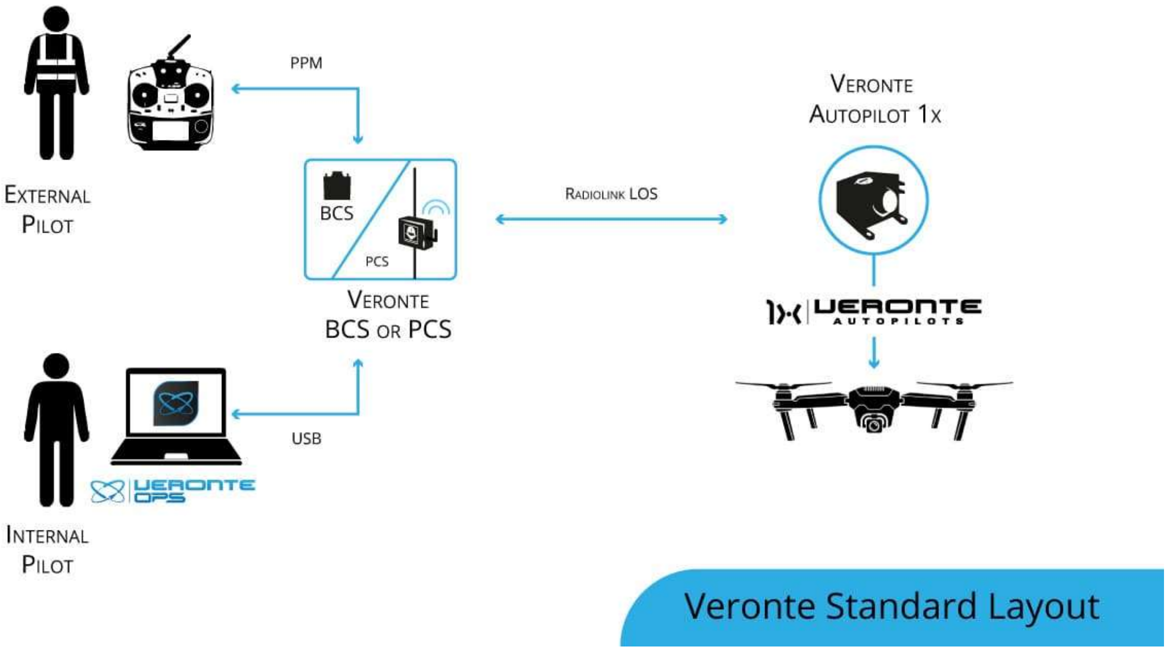

Figure 6-1. Veronte Standard Layout

6.3.1. Air communications

6.3.1.1. Line of Sight

This section comprehends the communications when the airship is still on sight, when the distance between the Ground Control Station (GCS) and the vehicle allows a useful and safe operation without any noise or information losses.

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Standard setup

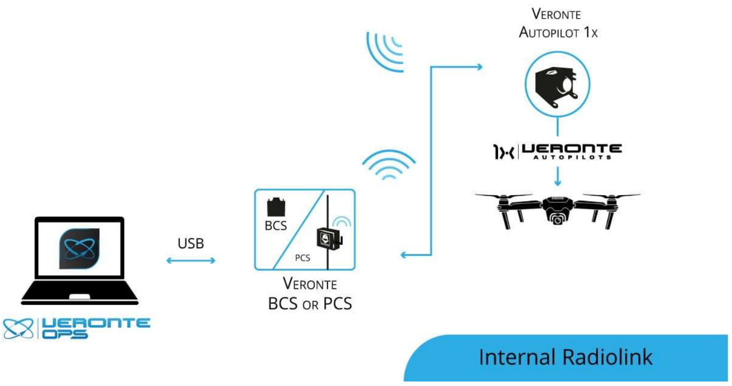

Figure 6-2. Connection via Internal Radiolink

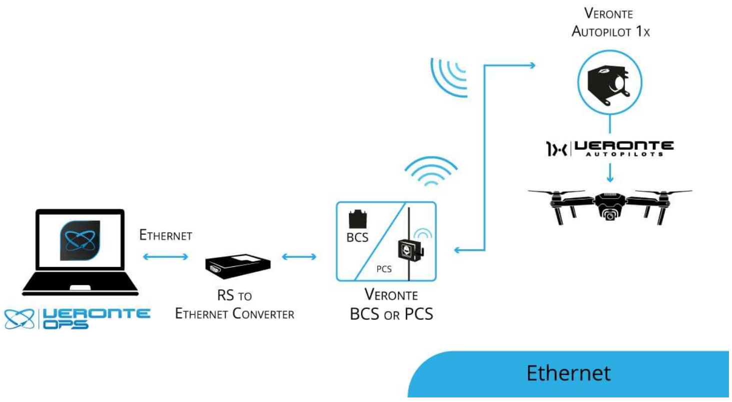

Figure 6-3. Connection via Ethernet

External radiolink

For increased range, bandwidth or channels are needed.

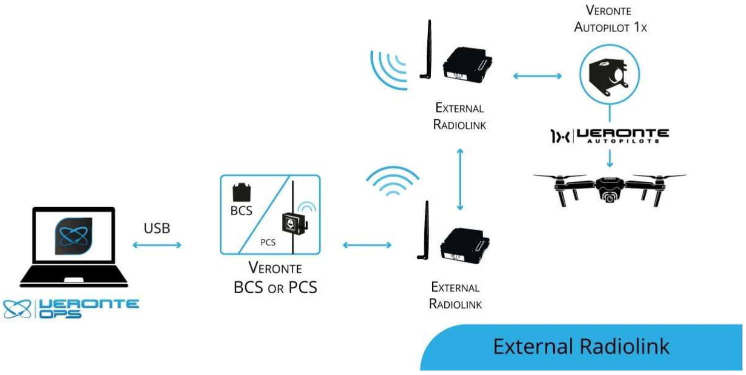

Figure 6-4. Connection via External Radiolink

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Tethered

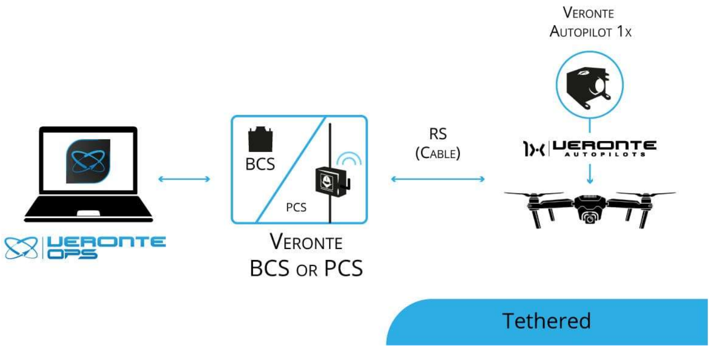

Figure 6-5. Tethered connection

6.3.2. Beyond Line of Sight

This section comprehends the communications when the airship is not on sight, when the distance between the Ground Control Station (GCS) and the vehicle does not allow a useful and safe operation without any noise or information losses.

External equipment must be used to extend the communication so the control station and airship could perform good communication.

6.3.2.1. Internal 4G + Veronte Cloud

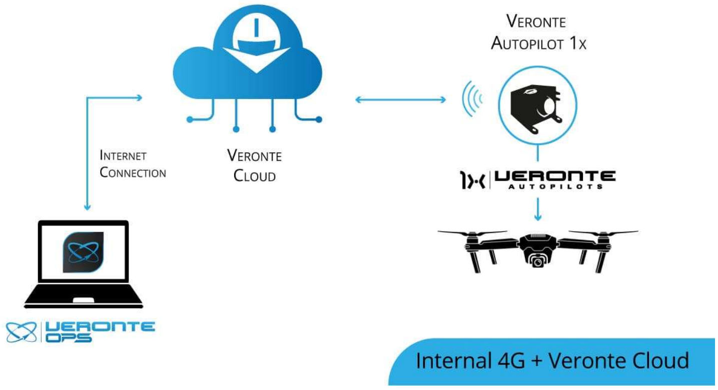

Figure 6-6. Connectia via Internal 4G + Veronte Cloud

External Internet access + Veronte Cloud

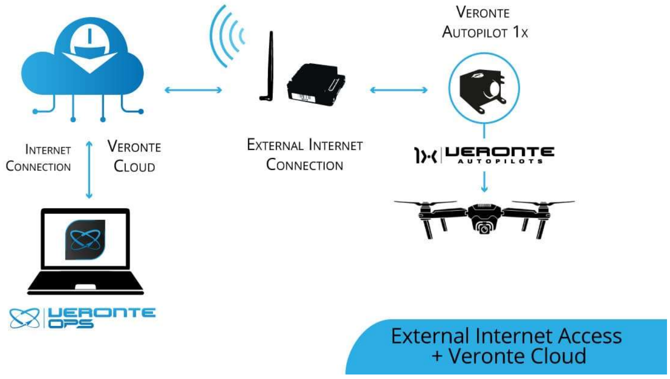

Figure 6-7. Connection via External Internet Access + Veronte Cloud

External Satellite communication

For maximum reliability

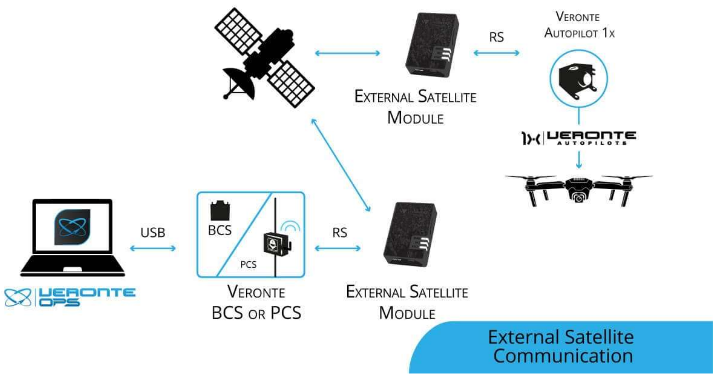

Figure 6-8. Connection via External Satellite Communication

Remote GCS

For remote solutions with LOS backup operator

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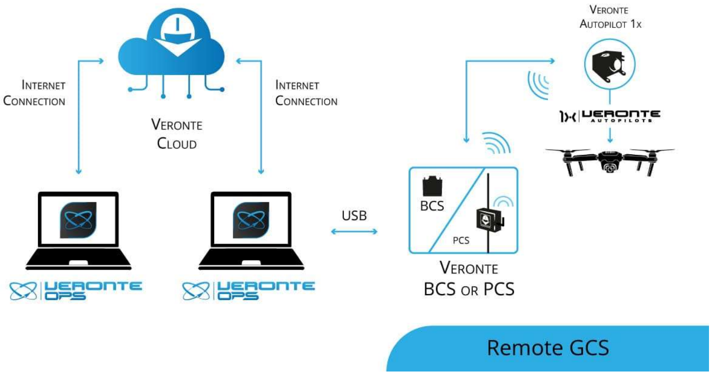

Figure 6-9. Connection via Remonte GCS

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