UiT The Arctic University of Norway

Integration of UTM and U-Space on Norwegian continental shelf

An overview of progress and regulations related to U-Space

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Master’s thesis in Aerospace Control Engineering, STE-3900, Spring 2022

Faculty of Engineering Science and Technology

Assignment text

General objectives
The use of UAVs (Unmanned Aerial Vehicle) or drones is becoming increasingly more popular and frequent in general use, but also within oil and gas production for various purposes. The airspace in and around oil and gas production fields is often occupied by helicopters, on rescue and search missions, shipping materials and people to and from the platform. With the research on UAVs and starting to make use of them, a crucial part of the introduction process is how to navigate safely and within regulations in accord with laws and other air vehicles in the airspace. Thus, the general objective for this project is to perform a preliminary study into Unmanned Traffic Management and U-Space. In addition to how to integrate this on Norwegian continental shelf, with all the existing Manned Aerial Vehicle operations in the airspace.

Subtasks

- Perform a literature review on Unmanned Traffic Management and U-space in general and for the Norwegian continental shelf.
- Review the EASA roadmap for U-space, and discuss its purpose, impact for operators and technological requirements.
- Establish a framework for automatic scheduling, flight logistics and path planning to ensure continuous operation, in the Norwegian continental shelf.
- Suggest a plan for how to integrate the Unmanned Traffic Management in the already occupied airspace, while not delaying the ongoing airspace traffic.

Summary

In this master thesis, we present an overview of the U-Space and Regulations in Europe, while also taking into consideration the progression of the integration of both parts in Norwegian airspace over the Norwegian continental shelf. This thesis is mainly separated into three parts.
The first part is taking a look into the European Union's roadmap/plan for establishing an Unmanned Aircraft System Traffic Management (UTM) and how they plan to develop their system into a single European sky. The end goal is that essentially every operator of a drone can do so all over Europe without having any issues with crossing borders or different regulations.
The second part of the thesis is dedicated to a detailed insight into the technical side of a UTM, the different layers, examples of which systems are the most relevant to be utilized on the Norwegian continental shelf.
The third part of this thesis is dedicated to looking at the regulatory side of things, in regards of the UTM system in itself, different factors of drone operations, requirements for every part of an operation. In addition, discussing and concluding about everything we have been though in the thesis. Additionally, there are uses cases where everything comes together to see how it would work in practise and in certain scenarios.
In the final part of the thesis the previous parts of the project will be discussed, as well as drawing final conclusions to the project.

Preface

This thesis is submitted as the partial fulfilment of the requirements for the Master's degree in Aerospace Control Engineering at the UiT - The Arctic University of Norway. The project is based on the proposed assignment given by Equinor ASA during the spring of 2022, and thanks to my neighbour Lars Seeberg for connecting me with them.

I would like to thank my main supervisor, Prof. Raymond Kristiansen, for his valuable advice, regular support, encouragement, and generally good spirits. I would also thank Espen Wanvik and Alexander Blokhus at Equinor ASA for their cooperation through this project and help when needed.

Finally, I would like to dedicate this project to my late grandparents and thank everybody close to me during the entire 2 years of my master education, for their support and understanding.

Contents

Abbreviations:

- International Civil Aviation Organization (ICAO)
- European Union Aviation Safety Agency (EASA)
- Single European Sky ATM Research (SESAR)
- European Union (EU)
- Air Traffic Management (ATM)
- Unmanned Aerial Vehicles (UAV)
- Unmanned Aircraft Systems (UAS)
- Unmanned Aircraft System Traffic Management (UASTM/UTM)
- Ground Control Station (GCS)
- Air Traffic Control (ATC)
- Air Navigation Service Providers (ANSP)
- Very Low Level (VLL)
- Global Navigation Satellite System (GNSS)
- Electronic registration (e-registration)
- Electronic identification (e-identification)
- Detect and Avoid (DAA)
- Unmanned Aircraft (UA)
- Beyond Visual Line of Sight (BVLOS)
- Urban Air Mobility (UAM)
- U-Space Service Providers (USSP)
- Visual Line of Sight (VLOS)
- Extended Visual Line Of Sight (EVLOS)
- European Economic Area (EEA)
- Concept of Operations for European UTM Systems (CORUS)
- System wide information management (SWIM) European Air Traffic Management Architecture (EATMA)
- North Atlantic Treaty Organization (NATO)
- Air Traffic Service (ATS)

- Search and Rescue (SAR)
- Vertical Takeoff and Landing (VTOL)
- Electro-Optical/Infrared (EO/IR)
- Electronic Support Measures (ESM)
- Synthetic Aperture Radar (SARa)
- Laser Imaging Detection and Ranging (LIDAR)
- Signals Intelligence (SIGNIT)
- Automatic Identification System (AIS)
- Global Positioning System (GPS)
- ATmospheres EXplosives (ATEX)
- Common Information Function (CIF)
- Flight Information Management system (FIMS)
- Supplemental Data Service Providers (SDSP)
- Supplemental Data Provider (SDP)
- Maximum Take-Off Mass (MTOM)
- Light UAS operator Certificate (LUC)
- Instrument Flight Rules (IFR)
- Visual Flight Rules (VFR)

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1 Introduction

1.1 Background

The Unmanned Aerial Vehicle (UAV) is not a new invention, neither is traffic systems and traffic laws. The origins of the UAV traces back more than 100 years to airplanes implemented with autopilot before becoming aerial torpedoes produced for military purposes during World War I. The United Kingdom was the first to produce a UAV that could take off, execute a mission, and then return safely as a pilot-less target aircraft, simulating new and improved enemy fighter aircraft. The development efforts continued through the Korean war and World War II, even the Germans made an attempt at making an aerial torpedo, which was launched 3200 times and claimed about 100 lives, ultimately having little impact on the war [1]. The United States of America (USA) split its efforts into different concentration point in cruise missile and UAV in the 1950s. Thus, during the Cold War, they were applied as intelligence, surveillance, and reconnaissance systems, which ultimately was becoming an essential resource to have. The application continued, with limited success as weapons delivery platforms but thrived as an intelligent, surveillance, and reconnaissance system, all the way to the end of the Vietnam War, when hostilities ceased. The 1970s and 1980s were led by Israeli developments for the UAV, which made the electronics cheaper to produce and smaller in size, and their capabilities increased with the possibility of jamming (location of radio locators) live data and parameter gathering. They produced and sold big quantities of UAVs to the US, who faced several technical difficulties. The US interest in UAV development was born again for the 1991 Gulf War, it was then the US took over as the leading developer of the UAV, improving on the Israeli development, implementing more abilities, making them cheaper, more reliable, easier to launch and use [2]. The common element throughout the 20th century was that the main motivator of UAV development was military conflict/war.

Figure 1: MQ-9B SkyGuardian (UAV).
Credits: Photo Courtesy of General Atomics-Aeronautical Systems Inc.

In recent times we are seeing the use of UAVs and Unmanned Aircraft Systems (UAS) as becoming increasingly more popular and frequent in general use for both recreational and professional purposes, in agriculture, construction, film production, delivery services etc [3, 4, 5]. With Amazon being in the forefront, having analysed the regular parcel delivery market and trying to compile the most efficient parcel deliveries through UAVs and UAS [6]. This will in the end inspire or pressure other companies to apply similar solutions and thus make the need to define regulations, laws, and systems that make the usage of UAVs/UAS safe, effective, and not interfering with external factors (existing operations, environment, living creatures such as birds).

UAVs and UAS have come a long way in terms of development and research the last decade or so, both recreational and commercial, and the number of application areas for UAVs have increased and still do. DJI have for a number of years now sold different types of UAVs for recreational use by civilians and continue to develop the UAVs' capabilities. New companies are founded regularly that have their own focus point of UAV or UAS development, for example Griff Aviation concentrating their focus on UAVs with heavy lifting abilities, which would have many application areas, and already existing companies focusing on making their technology applicable for drones, such as FLIR thermal optics. As it is with anything new being applied, there will be made rules for the units and the systems they are a part of to make sure that the technology is safely used and cannot be abused. Only in recent times have UAV and UAS been perceived as a big enough part and separate community to other aviation occupants, as to establish the need for separate regulations.

1.2 Literature review

Liu et al. published a review article in the fall of 2020 [7], where they present a survey from the perspective of Air Navigation Service Provider (ANSP) about the operational and technological freedom of access for the UAS, in the technical and regulatory view. The main objectives of the paper, as described by themselves, are to describe what typical ANSP-supplied UAS Traffic Management architecture is required to facilitate all types of civil UAS operations, identify three major ANSP considerations on how UAS can be accommodated safely in civil airspace and outline future directions and challenges related with UAS operations for the ANSP.
The authors of the paper goes into great detail about airspace organization and management for UAS civil operations. It focuses on the different types of UAS and airspace usage/access, different types of structures for airspace and organizations, the adjustments needed to be done on the dynamic airspace throughout time and about the management of geofence (airspace management for UAS on the individual level). Furthermore, the authors of the paper explains the challenges, current state-of-the-arts solution and the representative results for the solutions, for the essential components of Air Traffic Services (ATS) provided in UAS-ANSP coordination and the key technological enablers for UAS-ANSP interaction. Moreover, they describe the future directions and challenges for the integration and operation of unmanned aircraft system operation in national airspace.
In the end they conclude that ANSP should help develop a common framework that describes how the different types of UAS operations are to be handled in a Unmanned Aircraft System Traffic Management (UTM), and the three key management considerations to a successful UTM will combine to form a three-layer safety net. The three keys being: "how airspace is structured and managed with the aim of making the best possible use thereof, how traffic services and instructions are provided during the UAS flight executions and what essential UAS elements are required to meet airspace and service requirements". Additionally, the paper looks at these key considerations in an ANSP context, AOM, ATS provision and Sense and Avoid (SAA) technology together with other technical enablers, to form the safety net mentioned previously.

Cummings et al. published a paper in 2007 as a part of the international C2 journal [8]. The

paper gives a good review of the challenges of having one operator for multiple UAVs. It defines the human supervisory control of one and multiple UAVs, before it analyses previous research and literature to examine potential trends in supervisory control research of multiple UAVs. Additionally, the paper demonstrates that increasing the autonomy across hierarchical control loops provides a number of advantages to a man-machine control partnership, when it comes to increasing the capacity to operate multiple UAVs. In addition, taking a look and considering the several disadvantages that also follows with the increased autonomy.
Firstly, the paper makes an overview of supervisory control of multiple UAVs, how it works generally, how it could work for multiple UAVs and which improvements might be added to take the step towards operating multiple UAVS as efficiently and safely as possible. Secondly, the different levels of automation are explained and what is needed to make a system work for multiple UAVs, with taking into consideration the advantages and disadvantages of increased autonomy. Furthermore, the paper reviews older papers and previous research about operating multiple UAVs and the relevant topics that follows.
Lastly, the paper concludes with "Despite the aggressive development of these multiple UAV/UAS control technologies, the research community is only beginning to grasp the nuances of human interaction in the cognitively demanding environment of multiple vehicle control", that with increased autonomy in the control hierarchy, the number of UAVs that is possible to operate will likely increase as well. The real number actually depends on a variety of different factors. In addition, that there is a serious drawback in automation bias that could lead to errors. The paper states that the "critical lesson" to be learned from the analysis is that "the success of any UAS, and more generally multiple command and control task management, is not just contingent on high levels of autonomy, but more linked to robust system automation strategies that account for human operators' cognitive abilities, both positive and negative".

In 2021 Quan et al. published a paper, with the support of Beijing National Science Foundation, about a solution for the problem of airspace having dense traffic [9]. As the UAV market and utilization increased, they saw several types of related research about either traffic network, safe route creation and swarm control, but none where every part was considered. Therefore, they propose a sky highway with basic operation for Vertical Take-Off and Landing (VTOL) UAV, where traffic network, route and swarm control are all considered to achieve a trade-off between volumes of UAVs and safety.
The sky highway proposal builds upon the general traffic network model. It can be decomposed into the airway model and intersection model. Also, the separation distance between two UAVs is taken into consideration. Sky highway makes use of geometry design that aims at separating UAVs in two different carriageways, this puts constraints on the intersection radius and the intersection angle of two airways. In the airway and azimuth connection, the highway flight mode is adopted; while, in the hub, rotary island modes are adopted. The concepts are designed after the rules of cars on the highway and in roundabouts. In highway mode they also think of how faster UAVs can overtake slower ones without slowing down. Additionally, in rotary island mode all UAVs entering the intersection will perform a clockwise or anticlockwise rotation, like in a roundabout, until they are at the entrance to the next airway. With such methods, the traffic flow will increase overall, as they demonstrate in the paper with simulations and real test flight experiments.
The paper concludes with that the sky highway design for dense traffic shows great potential and is effective in increasing flow, but also considers that there is still much work to be done to perfect the design by adding more complexity to the network and also by taking into consideration the impact of some practical applications like the environment, communication, the flight capability of the UAVs and so on. All to help the design gain better quality, reality, and efficiency of management.

Lee et al. published a paper in 2020, with the support of the European Union's Horizon 2020 research and innovative program [10]. They propose an algorithm that aims to provide an efficient and practical tactical de-confliction solution for UAVs, where the main idea is to expand the differential geometry concepts applicability to polygonal obstacles, and to utilise its ability to compute the minimum heading angle change to avoid obstacles. The algorithms key idea is to detect the line-of-sights with potential conflict and change the heading angle, all while considering various performance measures, such as minimum separation, flight time to reach waypoint and computational cost. To verify the safety, scalability, and efficiency of the algorithm they have compared it to other collision avoidance methods by simulations.
The paper shows how they set up the algorithm to detect an obstacle and the points that are the most endangered of collision with respect to the line-of-sight, and then avoids collision by ensuring the minimum separation and change in heading angle, whilst considering the chance of collision with another intruder unit. In the simulation when they compare with other collision avoidance methods such as Artificial Potential Field method (APF) and Particle Swarm Optimisation method (PSO), the results shows that while it might not be the most efficient method in some specific points, it is overall the most efficient and safe way.
The paper concludes that the proposed collision avoidance algorithm has analytically proved that the minimum separation is guaranteed. In addition, it proves that the total flight time is close to optimal with low computational cost, which points to that the algorithm can be a practical and efficient solution for UTM.

The new regulations on airspace organization were published May 2009, on the website Lovdata.no by the Norwegian government's ministry of transport [11]. Since then, it has been changed/updated a number of times, but the latest change/update came in 2021. The purpose of the publication is described in paragraph 1, and states: "The Regulations shall lay the foundation for organization of airspace in the form of flight information regions, Instrument Flight Rules (IFR) routes, airspace areas, airspace classifications, prohibited areas, restriction and danger areas with the primary goal of achieving a safe and effective traffic flow taken into account by all users."
Additionally, it has detailed information about all topics within airspace organization. Also, detailed descriptions about how to apply to make changes to the regulations and what the what the applications should contain as a minimum.
The main takeaway we got from the regulations were the classification of the airspace. It will be an important piece of information to know when moving onward.

In December 2015, The Norwegian governments ministry of transport, their own regulations about aerial vehicles that do not have a pilot on board, to their law website Lovdata.no [12]. It has also been changed over the years, with the latest change/update published in November 2020. The purpose of these regulations is described in the first paragraph, and states: "The purpose with the regulations is to lay down certain special provisions for aircraft that that do not have a pilot on board on the basis of the special type of aviation that this is and certain provisions for model flying"
The regulations details rules and laws that must be followed by model plane operators and other Remotely Piloted Aircraft System (RPAS) operators, such as alcohol exposure, weapon attachments, insurances, safety measures, no-fly zones, and supervision just to mention a few.
Just as the previous paper, there isn't a conclusion to the regulations, so I will mention the main takeaway. After going through the regulations, the classification of different RPAS and what laws and rules that apply to the specific category will be key knowledge to know in my master thesis. In addition to safety measures that must be taken, and which organizational parts must be in place to be in accordance with the regulations.

The Norwegian governments ministry of transport published in December 2016 a website article about regulations on air traffic rules and operational procedures [13]. It has been changed multiple times, but the newest update/change came in September 2020. The publication is all about traffic rules in the Norwegian airspace in accordance with the European rules Standardised European Rules of the Air (SERA). This comes from the fact that Norway is a part of the European Economic Area (EEA) agreement, which makes Norway adhere to certain European approved rules and regulations, in this case the SERA rules.
The publication details common rules, collision avoidance procedures, travel plans, rules about weather conditions for different types of flight, visual flight rules, IFR, short about airspace classification, ATS, communication rules, consideration for civil aircraft and more.
Since the publication does not contain a conclusion, I will mention the information that has been found the most relevant to consider when going forward. Key parts from the publication are the consideration for civil aircraft, all the rules about procedures and the fact that the SERA rules is applied in Norwegian airspace.

Lappas et al. published a paper in 2020, in cooperation with various researchers such as M. Tantarini, about EuroDRONE a UTM demonstration project, funded by the EU's SESAR organization [14]. The purpose of the project is to examine the applicability of different technologies, architectures, and concepts, to promote the cooperation of the relevant stakeholders and to identify problems, misconceptions and needs that has to be addressed before the realisation of U-Space will be successful. The paper states that the objective of the EuroDrone project is: "to develop, mature and qualify U-Space functionalities as provided by Single European Sky ATM Research (SESAR) JU/CFP and test them in Greece."
The paper details the various focus areas in the project, such as Europe's conceptual UTM framework where they explain how they form a U-space and what key elements the different levels of U-Space are comprised of. Furthermore, the architecture of the EuroDRONE UTM is explained with what purposes the different elements like the cloud network, the arrays, the infrastructure, and Operational Sequence have and how they combine to form a functional UTM system. Finally, they go through the actual flight trials. How they are set up, with what preparation and testing had to be done before an actual flight. The first actual flight tests and their objectives surrounding demonstrating different functionalities on the drone, testing the automation of the system, the elements of the U-space like the "Foundation services" and "Initial Services", and how it reacts and handles actual airspace and obstacles.
The paper closes with the team recommending what to further develop and pursue, like availability of robust mobile network, robustness of critical hardware and increased autonomous UTM-ATC links and operations. In addition, to concluding that the "EuroDRONE was able to validate multiple complex UTM technologies and services through two practical demonstrations which took place in July and October (2019) at the Airport of Missolonghi in Greece with the following objectives met: 1. Innovative vehicle to infrastructure link (V2I), integrated to a self-learning UTM platform, with a capability to share flight information in real time. 2. Demonstration of end-to-end UTM applications focusing on Visual Line Of Sight/Beyond Visual Line Of Sight (VLOS/BVLOS) logistics and blue light services. 3. Advanced autonomy, logistics applications."

Fall 2020 the paper [15] was publicized by author Mateusz Kotlinski, and it describes the way UTM was integrated into Polish aviation law and focuses on showing how important the proper legislation and cooperation of different stakeholders are to implement concepts as complex as UTM and U-space. The main purpose of the paper is to use Poland as an example of one of the several states which started their early development of regulation and how the regulation was used in order to implement the UTM system in Poland called PansaUTM by Polish Air Navigation Services Agency - Air Navigation Services Provider in Poland.

The paper firstly introduces you to the history of the Polish aviation law and how it came to the point where they had to determine the regulations regarding UAVs, which meant to compile the different requirements of VLOS and BVLOS flight, the responsibility of the operator, explain the role of the Polish Air Navigation Service Provider (PANSA) and describe the licensing of the UAV operators. The following chapter explains PansaUTM and how it works, with detailing how it came to build their own UTM system concept. In addition, it explains how it was received by peers when purposed and how it became the first operational system in Europe to involve ATC with fully working collaborative ATC interface. Lastly, the paper describes the further development of the UTM and U-space system and plans to add capability to cooperate with other systems.

The conclusion is that the development and future of U-space is promising, with further research being done. Numerous organizations will make different approaches to the concept, and the ecosystem of the U-space will benefit from it when all the good parts can be compiled into a common standard for UTM system. Also, the research being done on technology and drones, which will complement the development for U-space. To summarize the paper states: "As the whole concept is being shaped, the future regulations should be flexible enough in terms of the U-space architecture to be not counterproductive to already existing achievements on this field."

The authors Skultety and Poljak published the paper [16] in cooperation with The University of Zilina in Slovakia in 2019, as one of the scientific outputs of the project "Broker centre of air transport for transfer of technology and knowledge into transport and transport infrastructure". The objective of the paper is to assess the obstacles, possibilities, and approaches to the integration of UAVs into the current airspace.

The paper goes through the various difficulties of UAS in terms of their integration into a complex and modern system such as ATM, seen in Figure 2. The first part of the paper outlines and systematizes the theoretical knowledge of UAS and categories of airspace sharing entities, such as high altitude long-endurance UAVs, commercial aviation, helicopters, government, and military with more. Additionally, it briefly explains the infrastructure of the sector and the development over the last years and years to come. The main part offers an analysis of the current proposals of UTM and new flight rules in various countries of the world, such as the UTM by NASA (USA), U-space in Europe, Civil UAS Aviation Operation Management System (UOMS) in China and Japan Unmanned System Traffic and Radio Management Consortium (JUTM) in Japan. Afterwards, the paper offers up its findings and recommendations where they explain the different takeaways of analysing the different approaches from the various places and proposing new flight rules based on the gained knowledge from the analysis.

Lastly, the conclusion is that there is a large number of different efforts to make the integration of UAS as secure and efficient as possible. Additionally, they determine with the various development and research being done, that if the different countries and organizations has a certain level of competition, standardization, and cooperation, the collective international UAS flights and regulations will be as efficient, secure, and simple as possible.

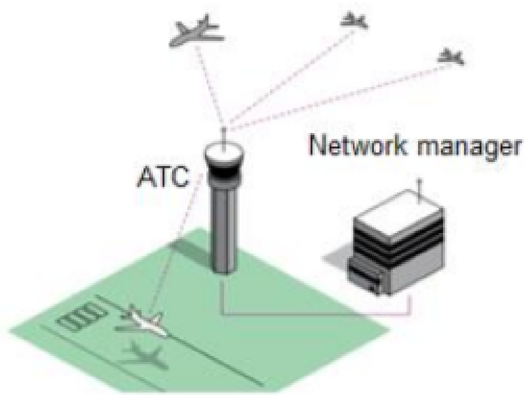


Figure 2: Current ATM System.
Credits: Photo Courtesy of F. Skultety and J. Poljak

In October 2021 Hussein et al. published the paper [17], and it aims to identify essential/key enabling technologies that are required to develop a customizable and a safe UAV system for the integration of UAVs into non-separated airspace.
Firstly, the paper details what the main usage areas for the UAV system is and how it is enabled in the specified areas. They are based on the COMP4DRONES research project, such as transport, construction, logistics, surveillance and inspection, and agriculture. Then they break down the usage to find the specific type of components that is being enabled in each area, so that they then again can find out which technologies are needed to make the components work. Furthermore, the paper then goes on to describe how the key technologies are identified and put in a layered architecture, before presenting the key technologies in detail. Secondly, the contributions of the COMP4DRONES project are described and categorized, based on the identified key enabling technologies. They are categorized into four groups which are the safe autonomous decisions, minimization of the system design and verification efforts, integrated modular reference architecture, and trusted communication.
The conclusion of the paper is that the analysis that has been presented, where the key enabling technologies has been identified through use cases, structured, classified based on the COMP4DRONES project. Then using the identified key technologies, improvements were proposed and detailed.

Lin et al. published the paper [18] in May 2020 . The purpose of the paper is to introduce the design concept of the hierarchical UTM in Taiwan. In addition to presenting a number of trial runs of regional UTM as preliminary experiment to focus on the viability analysis of UTM system performance utilizing ADS-B like communication for UAVs. The ADS-B like infrastructure is using Long-range wide area network (LoRa) On-board unit (OBU) and Automatic packet reporting system (APRS) OBU as the foundation for the concept system.
The paper first goes through different types of conceptual UTM structures that are either being developed or being used in certain countries/regions, as well as explaining the different components to a UTM system. Then it goes into detail explaining the system that are going through test run in Taiwan, how it is set up with the system infrastructure and explaining the different types of ADS-B like OBUs. Lastly, it goes through the system verification process, where it is described how LoRa Ground Transceiver Stations (GTS) are deployed and tested pre-flight, before doing actual LoRa verification flight test. In addition to describing the same verification tests for the APRS GTS and

going through several technical elements of the UTM system, such as system redundancy, the UTM centre, 6 Degrees of freedom (6DOF) surveillance and data suppression and Controller-to-Pilot communication (CPC).
The conclusions being drawn are that after the deployment and setup of the UTM system, the trial runs that were done came back with acceptable measurements to prove that the GTS redundancy concept works well and gives a direction for further flight plans on GTS. Emphasising the importance of surveillance technology to open UAS in regular commercial services, all while giving a demonstration of how effective UAV surveillance is when using ADS-B like OBU to GTS deployment in UTM systems.

The paper [19] was published by Alarcon et al. in September 2020. The main objective of the paper is to address safe integration of UAVs through the SAFEDRONE European project, which then again has the main objective of performing very low-level (VLL) operations that demonstrate the integration of different types of platforms (Manned and Unmanned) in the same airspace using novel U-space procedures and services. The paper states that it: "presents the work carried out in the framework of the SAFEDRONE European project. This project addresses the "safe integration of drones" topic of the SESAR 2020 Exploratory Research and Very Large-Scale Demonstration Open Call. It covers the demonstration of proof-of-concept operations for drone traffic management within a representative environment."
First point is the introduction to the problem and the SAFEDRONE European project, which this paper is based upon, explaining the several elements that compiles the project and paper. Secondly, you are presented a description of the U-space demonstration environment, which includes a high-level architecture of their U-space system. In addition to a brief description of the location and aircraft used in the project's demonstration experiments. Furthermore, the next chapters present the design of the procedures related to the no-fly zones, the study related to the separation with manned aircraft and the procedure to integrate autonomous non-cooperative detect and avoid technologies within U-space.
Lastly, the paper concludes with three main points: 1. The geofence procedures is the most efficient way to deal with avoiding and exiting no-fly zones vary with numerous elements, but for the mass-market the manual control overtake is the most efficient. 2. The use of surveillance information to ensure the separation with manned aircraft, is a key element to efficient use of shared airspace. And that communication with ATC or the on-board surveillance system in the aircraft directly, could be considered a backup solution to non-equipped aircraft. 3. The integration of U3 services is technically feasible, but the technology itself is limited by the lack of maturity.

Back in 2004 Vachtsevanos et al. published through Georgia Institute of Technology the paper [20]. It introduces us to a novel architecture for the coordinated control of multiple UAVs and a differential game theoretical approach to formation control and collision avoidance. To illustrate the approach, a simplified two-vehicle example is presented to provide simulation results that verify the performance of the proposed algorithm.
As introduction we get a brief explanation of the current situation of autonomous coordinated control system, in addition to addressing the elements of the proposed control algorithm. The next part is about the system architecture, which is split hierarchical in three different layers. The "global knowledge" is the upper level where situation awareness and team mission planning are being done by the command-and-control centre. The "Local knowledge" is the middle level where formation control, obstacle avoidance and Fault Detection and Identification (FDI) is being controlled. And lastly, there is the lowest level "behaviour knowledge" which interfaces with on-board baseline controller, sensors, communication, and weapons systems (since the example situations are military

based). The last chapter is about the differential game approach to formation control, which goes through a brief introduction before going into detail on formation control as a pursuit game, the limitations of the approach, the two-vehicle example, collision avoidance and then the simulation results.
The paper concludes that by viewing the formation control problem as a pursuit game, they can determine important performance information about the formation. But that a mathematical analysis is required to obtain the information, which may be impossible. In addition, the variety of vehicles in the different formation makes the calculations harder since the dynamics for one vehicle or formation do not always fit another, and states: "The lack of a closed form solution could be remedied by using numerical methods; however, the dependency on the individual vehicle dynamics seem to be the price that has to be paid to obtain the performance measures mentioned above."

Konert and kotlinski published through the University of Warsaw, the paper [21] in 2020. It looks into the existing regulations and materials on UAV operations in U-space, as well as the economic and infrastructure elements of the existing concepts. The goal for the paper being: "to showcase the possible entities liable for damage caused by a drone flying in U-Space airspace and demonstrate the PansaUTM system – the backbone of PANSA's U-Space."
The first chapter introduces us to the consequence and potential of opening the aviation market to the civil use of UAVs. In addition to address regulatory standards and laws missing, regarding liability in case of an accident. The next chapter goes into detail while explaining the U-space concept(s) and the current state of the regulatory rule-making process. It goes through different drafts of defining certain aspects of laws and definitions from the SESAR blueprint, and draft opinions from EASA and the European commissions. The third chapter explains the pioneering in Poland with the PANSA UTM and U-space, also the current development regarding the implementation and certification with the polish Civil Aviation Authority. Finally, the fourth chapter reflects and discusses several potential scenarios where the question is "who is to blame?". This highlights the need for concrete directory for things like traffic control/rules, regulations regarding responsibility of the UAV and financial accountability in a theoretical accident.
The paper does not have a conclusion, but a summary which points out the main takeaways from the paper. The points are that there is a big job and economic market that follows the UA market, the implementation of UTM systems will create the need to make new or change existing laws regarding accountability and traffic. And that UTM systems have a long way to go being perfect, but current progress shows promising signs for U3 stage already.

Hermand et al. published the paper [22] in 2018 for the 26th Mediterranean Conference on Control and Automation. In the paper they propose a constrained control scheme to navigate a UAV to a desired position while making sure the constraints are satisfied. The goal of the paper is to connect the constrained control concept with UAV geofencing applications.
First, we get an introduction to geofencing and Explicit Reference Governor (ERG), while also explaining the goal of the paper. Then in the next chapter the problem statement is presented, explaining the technical parts of constraints and the two different constraints that is in the paper's focus. Thirdly, it discusses the development of a constrained control scheme for geofencing application. Where the first step is to pre-stabilize the UAV using control law, then going into detail on the ERG implementation to generate a complementary reference that can contain trajectories in an invariant set that is defined by the Lyapunov theory. In addition to explaining the two fundamental components of the ERG, the Dynamic Safety Margin (DSM), and the Attraction Field (AF). The last chapter goes through the Experiment setup with an AR drone in a space, with an obstacle and a wall that will be avoided through geofencing, and explaining the simulation results and showing

it through graphs.
The paper concludes with the result of the simulated experiment, demonstrating that for the case of UAVs evolving in a bounded space with obstacles and constraints, the proposed control scheme is effective. And that further work is still needed to develop a complete Control scheme for all types of constraints, like time-varying constraints and non-convex class constraints.

In 2020 the paper [23] was published by Lieb and Volkert for the 39th Digital Avionics System Conference. It makes a comparison between the European "CORUS ConOps" and the U.S. "FAA ConOpc", with focus on different elements like actors and responsibility, airspace access, contingency and emergency procedures, services for UAV and operator, airspace structures, remote ID requirements, separation procedures and UAS performance requirements for certain airspace and operations.
There are five main chapters and a conclusion in the paper. First chapter is an introduction to UAS and the market, and how it has increased in popularity in both recreational and commercial usage. The second chapter is a very brief explanation of the methodology of the papers coming chapters. Thirdly, we are explained the related works of both the European "CORUS ConOps" and the U.S. "FAA ConOps" on how they generally focus their efforts on different areas but are still comparable. The fourth chapter goes into a detailed comparison of both the concepts in different elements. Such as how the airspace classes are set up and structured, who the participants are in the system and which roles they have, the different services and supporting infrastructures of each concept, how each of the concepts classify and categorises the different types of operations and what underlies each class, how each concept have set up their airspace and separate them as well as what role the ATM has and how it cooperates. Additionally, the implementation of each of the concepts. The last chapter is a discussion chapter, here the main similarities like airspace separation and responsibilities of different roles, and the main differences like airspace categorization and the security aspects are discussed.
The paper concludes with: "the FAA UTM concept and the CORUS ConOps rely on comparable definitions of the aviation environment, on similar supporting UTM or U-space services as well as foreseen step-by-step implementation processes to be conducted in phases". The concepts have some different priorities in certain areas, but both could benefit from cooperation for a more common UTM concept.

Cho and Yoon published in 2018 the paper [24]. The main objective is to analyse urban airspace by incorporating a sufficient protection level of the surroundings environments as well as supplying operational requirements for UAV in use. This is done by proposing two types of geofencing, keep-in and keep-out (in a combination), to map out the usable airspace in the urban area of which is within the requirements set. All to assess the capacity of the airspace.
The paper presents its methods, concepts, and numerical analyses of the two different geofencing methods. Then it discusses the different elements and results of the hypothetical case and in the real 3-D geospatial dataset of an area called Gangnam in Seoul, South Korea. In the end the paper closes with a conclusion and presents ideas for future work. In addition, the paper goes into detail about what the fundamental differences between the two methods for geofencing, also they address the viability of using the same methods in other regions and countries with different regulation sets and rules.
The closing conclusion highlights the main points that the paper has gone through and summarizes the results in the hypothetical case and the real 3-D environment case, with the overall usability of a combined method was more sensitive parameter changes in the keep-out method than in the keep-in method. Also, that more work has to be done on the topic for it to be more refined for general use.

In 2018 the paper [25] was published by Davies et al. It goes through several different key technologies that enables BVLOS flights, developed to date and what possibilities each of the technologies could be opening, when optimized.
First, we get a brief introduction to the state of the operational UAV applications, like VLOS, Extended Visual Line Of Sight (EVLOS) and BVLOS, which is visually presented in Figure 3. Then it describes how FPV could be used as an alternative, as well as presenting Detect and Avoid (DAA) technologies. Furthermore, chapter three explains UAS traffic management system and some key attributes, afterwards chapter four presents different approaches to the use of radar for UAS applications. The last two chapters talk about different BVLOS missions already executed, the benefits and disadvantages of implementing artificial intelligence in UAS, and about UAS sensor fusion where the concept is to enable many sensory applications to work at once to minimise flight risk and enhance hazard detection.
The conclusion of the paper is that many technologies are already available at a functional level, but there are also several elements that need improvement like UAS communication and integration with ATM. In addition, safety and regulations should be prioritized parallel with the technical development of the entire UAS system.

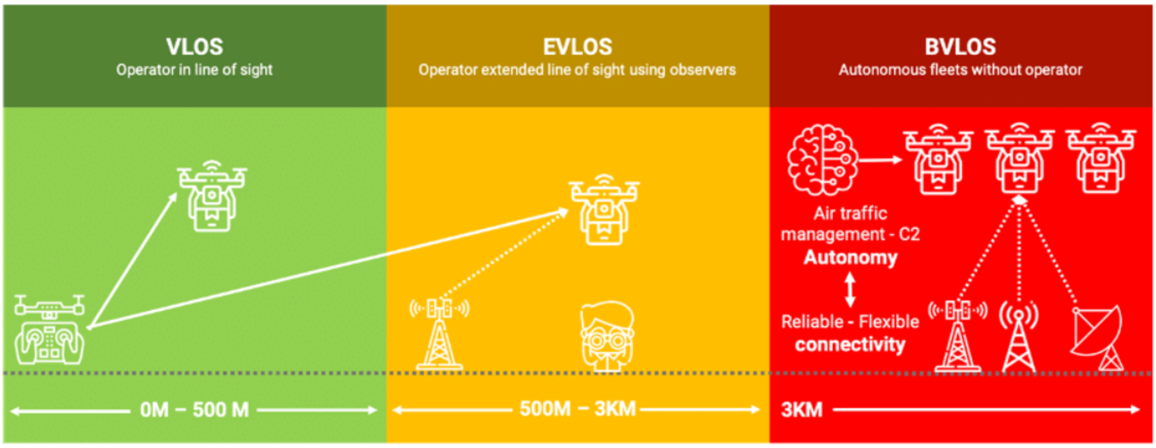


Figure 3: VLOS, EVLOS and BVLOS.
Credits: Photo Courtesy of elsight.com

In 2020 the paper [26] was published by Barrado et al. It presents U-space ConOps, produced around the new types of airspace volume (X, Y and Z) and its the relevant services provided in each new type. In addition, it proposes a new basis for aircraft separation in each type of volume, as well as address the high-level U-space architecture using European ATM architecture methodology.
First, we get an introduction of the UTM system architecture in the European perspective and its current status in Europe generally. Then chapter two presents the new U-space ConOps and how safety is addressed in the new structure, the associated services, and the new airspace classification. Chapter three goes into detail on the specific U-space architecture, its elements and how other projects have laid the foundation for the new concept system. Lastly, chapter four describes the foundations for the new separation standards to be applied in separation provision and conflict management.
To conclude the paper summarizes what it has presented throughout the paper and the necessary future research and development work.

The papers combined have given us foundational knowledge of some of the technologies, architectures, systems that is and may be implemented, experimentally or properly. How the various UAV units, entire systems, and additional technologies like different sensors, are advantageous or disadvantageous and in which scenarios these advantages or disadvantages apply. In addition, we have gained an insight into some of the systems that are actually in place and how it works in practise, as well as what the limitations are.

1.3 Objectives

This thesis subject was proposed by Equinor, and the main objective for this project is to perform a preliminary study into Unmanned Traffic Management and U-Space. In addition, to research how to integrate this on Norwegian continental shelf, with all the existing Manned Aerial Vehicle operations in the airspace.
The subtasks for this thesis are:

- For the purpose of implementing on The Norwegian continental shelf, review different literature on the topics Unmanned Traffic Management and U-Space.
- Take a look at the impact on operators, technical requirements, discuss and review the EASA roadmap for U-Space.
- Propose a system or plan to implement on the Norwegian continental shelf, ensuring continuous operation through planned scheduling, flight logistics and path planning.
- Propose how to implement the Unmanned Traffic Management to not disturb ongoing airspace traffic and occupied airspace.

1.4 Contributions and limitations

The main contributions of this project are as follows:

1. We have given an overview of the plan and timeline presented by the EUs official department, who is responsible for air safety, EASA. This includes explanation of what the proposed system is and why it is needed, as well as whom it will impact and how they plan to implement (with added timeline).
2. We have given a general overview of the technical concept of a UTM system and its variations, as well as deep diving into the different parts of the systems architectures. Additionally, given a recommendation what framework to implement on the Norwegian continental shelf and what we have based this recommendation on.
3. We have also given an overview of the most noticeably relevant regulations, cited directly from the official regulation documents. This is in regard to operators, the UAV itself, manufacturers, pilots, owner, services, and service providers.

The thesis is limited by the fact that the topic of UTM systems is still relatively new to the world and that even though a regulatory system is being established, there are still some holes needing to be filled in as they are found. This results in that any regulation already made, may be amended, or added to at any point, but we have made this thesis based upon the regulations and information that were available at the time, pre-2022.

1.5 Outline

The main part of the thesis is divided into seven chapters. Chapter one is the introduction to the thesis and presents background information that lays the foundation of initial UAV and U-space knowledge. This prepares us to delve deeper into the subjects in the next chapters.
The second chapter gives us a review of the roadmap for U-Space implementation. It goes through what comprises the roadmap and explains the different parts of it too, in addition to giving an insight of what the situation currently is in terms of progression in the plans laid.
The third chapter explains the framework for U-space system. It goes through the different architectural layers of the framework.
The fourth chapter goes through European Union regulations in regard to several aspects of drone usage and other aspects of drone missions.
The fifth chapter uses what we have been through to go over some use cases of examples of how U-space will work in certain scenarios.
Last of the main part is the sixth chapter that is dedicated to discussing everything in the thesis and the seventh section will be a conclusion to the thesis.
Lastly, comes the references and then the appendix.

2 Review of the EASA roadmap for U-Space

Drones are quickly becoming one of the fastest growing industries, with huge potential for several different types of applications. Hence, the number of drones operation and occupying the skies are growing and are expected to grow increasingly over several years to come. The development can be compared to the early development of airplanes, even though the revolutionary jump in development for airplanes came through World War I and World War II, which saw the technology stay and being applied and continuously developed long after. Eventually, aeronautical officials saw the need to regulate the airspace to increase safety, minimize risks and accidents [27].
It all started in the 1920s with the United States implementing airfield lighting to aid pilots in dark weather and/or bad weather conditions, before improving the concept to Precision Approach Path Indicator in the 1930s helping the pilot traverse the last stage to the runway by indicating the angle of decent [27]. This was adopted by the standards of the International Civil Aviation Organization (ICAO), whose mission it is to aid in diplomacy and cooperation for the 193 national governments who funds and directs the organization [28], for international use. Through further development and research, the situation nowadays is that there is so much air activity for different reasons, like military or commercial, that we need the airspace to be regulated, monitored, and organized to have everything flowing as smoothly as possible and for it to be as safe as possible with as little risk as possible.

Figure 4: The Griff 135 (UAV).
Credits: Photo Courtesy of Griff Aviation

In recent times we see that the use of drones, Unmanned Aircraft Systems (UAS) and Unmanned Aerial Vehicles (UAVs) (example shown in Figure 4) is becoming increasingly more popular and frequent in general use for both recreational and professional purposes, in agriculture, construction, film making, delivery services etc [3, 4, 5]. With Amazon in the United States being in the forefront, having analysed the regular parcel delivery market and trying to compile the most efficient parcel deliveries through UAVs and UAS [6]. Which will in the end inspire or pressure other companies to apply similar solutions to be able to compete in the market and thus make the need to define regulations, laws, and systems that make the usage of UAVs/UAS safe, effective, and not

interfering with external factors (existing operations, living creatures such as birds, environment, etc.).
Several diverse industry stakeholders have held studies resulting in many predictions based on the study estimates on the significant increase in the number of UAS operations within the European airspace. Particularly as a higher level of automation will be implemented as a result of technology development, which as mentioned before highlights the need for harmonised European regulations and framework.

The EU and European Union Aviation Safety Agency (EASA) has seen the recent development and increase in application for drones, and thus concluded with that for the airspace to continue to be as safe, organized and risk free as possible, a similar solution needs to be researched, developed, and implemented. EASA is the European Union's aviation department tasked with; draft implementing rules in all fields relevant to its mission about common safety, protection, certification and cooperation, approval and certification of organisations and products in EASA relevant fields (e.g. airworthiness), support and oversee member states in EASA relevant fields where they have shared competence (e.g. Air Traffic Management (ATM), Air Operations), promote use of European and worldwide standards, achieve the highest level of safety for EU citizens through cooperation with other international actors. It was established in 2002 and is the regulatory organization for the 31 EASA member states, they are also represented in four different locations in the world, Canada (Montreal), USA (Washington), China (Beijing) and Singapore with more than 800 aviation experts and administrators on hand [29].

Different countries have different rules and to simplify the use of a drone within Europe, the EU has decided to make the airspace as safe, organized and risk free as possible. This research and development initiative established in 2007 is called Single European Sky ATM Research (SESAR) [30] and includes drone operations as well as bigger aviation operations such as commercial flights, military planes, and helicopters. The US has also decided to implement safe drone operations with their ordinary aviation operations, by implementing an Unmanned Aircraft System Traffic Management (UASTM/UTM). The EU have delegated the task of establishing the same type of concept to EASA and SESAR, and their solution to the proposed issue is U-Space.

2.1 What is U-Space?

The first thing to know about U-Space is that it is not a specific and defined volume of airspace that is meant for drone used and segregated from the rest of the airspace as the name might suggest, it is actually a futuristic concept that provides an innovative set of services that is based and is relying on high level automation of functions and specific procedures and high level of digitization, to aid with efficient, secure, and safe access to airspace for a large number of drones. The automation and digitization may be implemented on either or both on the drone itself or as a part of the Ground Control Station (GCS) environment [31].
The U-Space is described by SESAR as an enabling framework developed specifically to facilitate any kind of routine mission, for all types of classes of airspace and environments, even the most overcrowded ones, all whilst addressing an acceptable interface with the Air Traffic Control (ATC), ordinary manned aviation, ATM/Air Navigation Service Providers (ANSP) and the appropriate authorities. U-Space is thought to have what it takes to ensure effortless and trouble-free operation for drones in all environments, and all types of airspace (specifically but not limited to Very Low Level (VLL) airspace). It covers all types of drone users and types of drones, as well as considering

all the needs for every type of drone operation [31, 32]. For an example from the Easy Access Rules provided by EASA [33], there are separate articles for each category of drone, 'open', 'specific', and 'certified', which have their own requirements to be able to be categorized and get authorisation to different airspace. Also, there are several classes and categories for the drones, so that the drone operator can find out where he can fly, what regulations he has to follow and what the requirements are for the drone and operator. The differentiating classes/categories are type of operation based on flight rules (Low Level Flight Rules, High Level Flight Rules, Visual/Instrument Flight Rules), traffic classes (class I through VII), class of airspace (class A – G), and as mentioned before UAS category (open, specific, and certified) [34].

SESAR published in 2017 the drafted blueprint for U-Space, a "vision of how to make U-Space operationally possible", with a very simplified visualisation of the concept taken from the draft seen in Figure 5. It suggests implementing U-Space over 4 phases with different sets of services which becomes more complex and advanced as it progresses, and it indicates the steady development through research and smaller projects in SESAR. All with the end goal of supporting the EASA and EUs aviation vision about strategy and regulatory framework on drones [32].

Figure 5: Simplified U-Space Concept
Credits: Photo Courtesy of SESAR [31]

Key principles are the foundation on which U-Space is built upon, and the delivery relies upon the following [31]:

- All airspace users operating in the framework of U-Space and all the people on the ground shall be guaranteed of their safety.

- Fair and unbiased access to the airspace for all users shall be ensured.
- When establishing acceptable requirements for safety, adaptability (management of failure mode included), and security (cybersecurity included), it will follow performance-driven and risk-based approach. All whilst considering the respect of privacy of citizens, data protection included, and lessening the environmental impact.
- Whilst managing the interface with manned aviation, it shall guarantee an adaptable, flexible, and scalable system which meets the demands of change in volume, applications, technology, appetite of the market and business models.
- Have the ability to accommodate high-density operations under fleet operator supervision, with multiple automated drones.
- When the requirements for U-Space are met, it shall accelerate deployment by acquiring standards and technology from other sectors.
- Leveraging, to the utmost possibility, existing infrastructures, and aeronautical services, including Global Navigation Satellite System (GNSS), and additionally those from different sectors (e.g. mobile communication services).
- Lastly, to support the business model of drone operators, by guaranteeing cost-effective and competitive service supply at all times [31].

The knowledge of what U-space is and what the key principles it builds and relies upon are, lays a foundation of our topical knowledge and lets us move on to acquiring the knowledge of how it will operate when applied. According to SESAR, U-Space, "subject to compliance with applicable regulations, operational limitations, and technical requirements linked to the operation of the drone", simplifies any kid of mission (e.g. transportation of goods, search and rescue, and agriculture related work) and future applications that are more complex such as urban air mobility. U-space is a service that everyone can make use of, both public drone users and private drone users (recreational and professional) will be offered the service, independent of mission type. Some services will be tailored by the relevant authority to meet necessary requirements for privacy and security. Additionally, performance requirements for service delivery, covering and structural elements (e.g. resilience, availability, continuity, and safety), will be established and stem from the criticality of the U-Space services. The comprehensive and adaptable range of services that form the U-space framework, relies upon agreed EU standards, and delivered by service providers. The services deliver key services for organizing the efficiency and safety of drone operations. However, it is not there as a replacement or replicate the functions provided by the ATC as known in ATM, but guarantees an acceptable and appropriate interface with ATC, manned aviation, and relevant authorities. The services may incorporate data delivering services, supporting services for drone operators (e.g. flight planning assistance) and more organized services (e.g. capacity management, tracking) [31].

There are several imaginable deployment architectures for U-Space based on service orientation and different business models, additionally the deployment of services, the interoperability and distributed responsibility among the many USSPs are the main arguments. The concepts deployment architecture was presented as seen in Figure 6, as well as presenting other variations. In a Concept of Operations for European UTM Systems project document created in 2019 by SESAR [35], the main alternatives are a trivial monolithic deployment of a unique solutions manager by a unique supplier or delivering more instances of management systems to supply a subset of services

and to provide consistent interoperability.
In the concept document it is said that most likely there will be two types of services, those that can operate in parallel and those that work best if unique. Also, there are services that the users may be interested and willing to fund and services made mandatory and will be funded by the state. Moreover, the concluded consensus is that it is not possible to approach the U-Space architecture discussion as a whole, by comparing monolithic vs federated, but instead consider them service by service [35].
Envisaging a unique USSP through monolithic deployment is a solution based almost solely on the fact that the limits between operator and principal USSPs are set magnifying the extent of the principal on all drone traffic management. The occurrence of this is when a specific supplier is mandated by a state, possible delays from validation/standards/demonstrations is required for services that manages the traffic that comprise the main sets of services and their interoperability, required supporting infrastructure is put in place through cost compensations, and when the interoperability standards are not yet published but the services are deemed necessary to be implemented as soon available. On the other hand, the set of principal services and the responsibilities of the principal USSP can differentiate depending on the chosen architecture, but that there will always be set of principal services realized by a system based on analyses, examples in demonstration projects, and expert reviews and chose by the governing state. This way the architecture will contain a state-mandated core of U-Space services, independent of the chosen set of services which will be centralised. The consumption of U-Space services for drone operators will then go directly through the chosen supplier or accredited service providers [35].

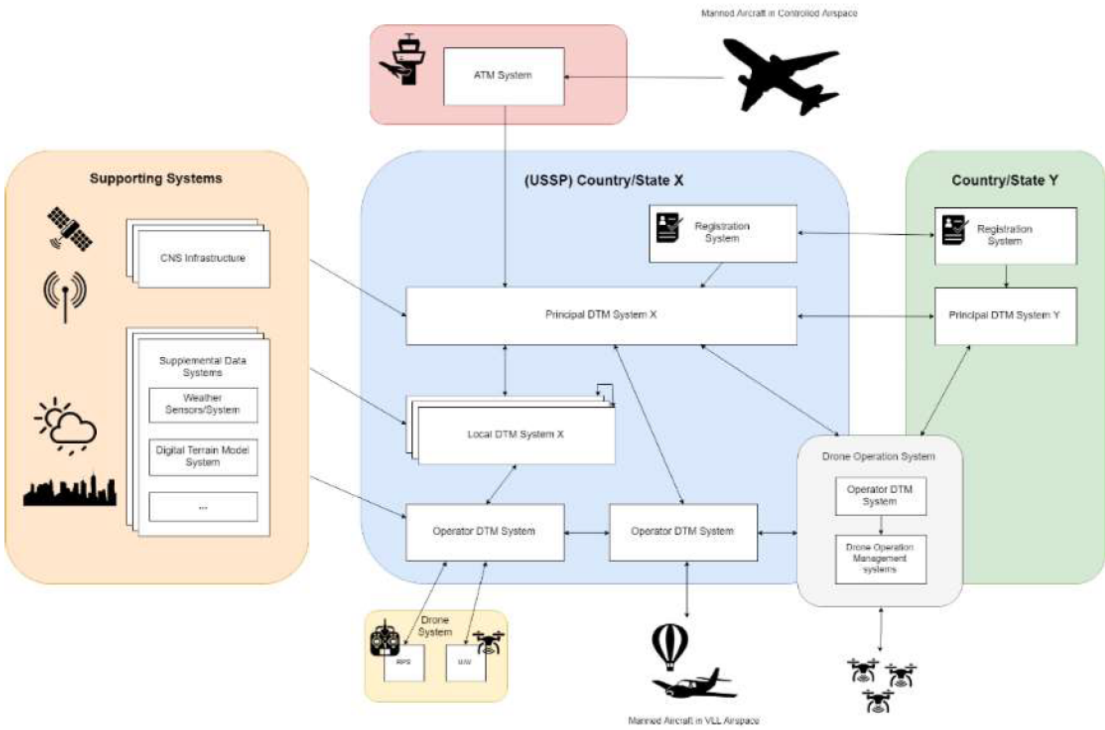


Figure 6: Deployment architecture overview
Credits: Photo Courtesy of SESAR [35]

2.2 Why do we need U-Space?

The new research and developments that have led to the increase in the drone market and increase in numbers of drone operations, comes with its difficulties and challenges. In [36] EASA indicate that to guarantee the safe handling of UAS operations on one hand, and additionally on the other hand ensure that in the whole European airspace the Unmanned Aircrafts (UAs) can utilize the existing air traffic conditions in a coordinated way, there exists a need to create a resilient regulatory framework. They also point to hazards to persons, property and air traffic increases parallel with the increase in both manned and unmanned aviation in a common airspace, if not addressed through appropriate extenuating measures.
Furthermore, the EU and the Commission wants to follow through on the climate commitments made with the Paris Agreement and want to lead the evolution to a healthy planet and a new digital world. As such, the emergence of U-space and UAS operations has provided the opportunity to switch to a greener alternative in aviation, especially in the 'open' and 'specific' UAS categories based on the fact that they utilize more electric and hybrid propulsion methods [36].

The authors of [36] describes it as "considered essential" to respond to the UAS operation growth with the development of the U-Space airspace and supplies of U-Space services, particularly in the for low-level airspace as per today, since they expect the current volume of traffic in manned aviation to become outnumber by VLL operations in the future. This is based on the fact that the current ATM cannot be seen as the sole solution for the upcoming UAS traffics efficient and safe management, since it is already reaching its limits in terms of capacity and also the fact that the expected UAS flying and traffic characteristics of the unmanned aircraft (higher level of automation and remote pilots not on board) differ from the ones in manned aircrafts. Additionally, the existing ATM system is based on a human-centric system concept and hence the severe number of highly automated UAS operations cannot be managed by humans. The human being cannot realistically manage and cope with the large numbers of UAS operations that is expected, even if the majority of processes and tasks that exists today are automated and digitized to be incorporated in the ATM system [36].
As a consequence, there has been found a need to create a European regulatory framework to complement the already existing European Regulations, overseeing UAS operations in the categories 'open and 'specific'. While the air navigation services supply for the safe operation of regular air traffic is being regulated by the Single European Sky framework, an additional traffic management system is needed to manage all the traffic of UAS operations. The complementary regulatory framework will be qualified to guarantee safety to all UAS operations management and will authorize and permit the coordinated implementation of U-Space. To facilitate more advanced and long-distance operations, the enabling factor will be U-Space. It will also guarantee the support for operations such as BVLOS operations or Urban Air Mobility (UAM), by providing the services that increases safety, efficiency, privacy, and security of the different operation types. Moreover, the need for the U-space framework and its services will increase in accord with the increase in volume and complexity of UAS traffic and level of automation incorporated in the different mission categories [36].
Furthermore, the UAS operators guarantee of cost-effective fair access to the airspace through a competitive market of U-Space services, highlights the need for the framework and U-space services. The paper [36] proposes that the EUs approach a UTM airspace can supply the building blocks to the foundation for common data exchange agreements, creating a cooperative framework where those who need it will be provided with the critical information that is available. This is for safety and security purpose, a guarantee of smooth and real time exchange of aircraft operators' position and UAS operators' aim, operational constraints and other critical data. The different stakeholders in

the European aviation community have had the possibility to comment on the proposed framework and regulations, this shows that also the users have been considered and consulted in the developing process. This resulted in over 2500 comments from 93 organisations, and from Figure 7 and Figure 8 we can see who had the most to say and specifically about what from the proposed regulations and framework. While consulting the European aviation community, they gathered information about who the stakeholders was and how strongly they were represented. Additionally, they also gathered information about which articles created the most discussion.

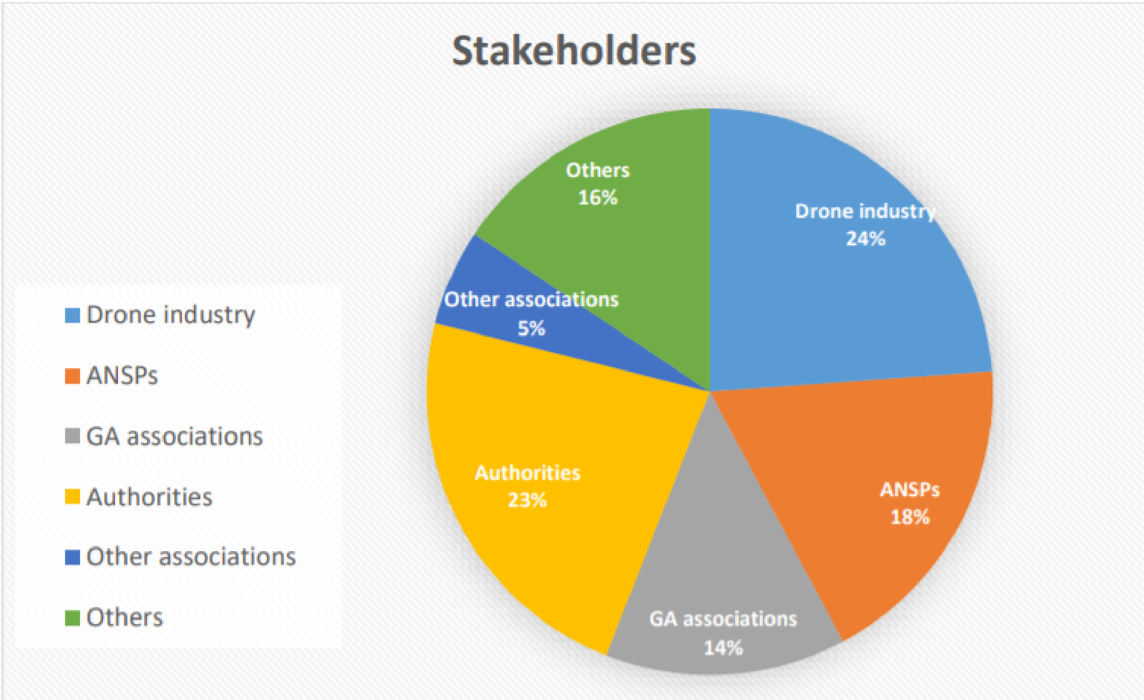


Figure 7: Distribution of the comments received per type of stakeholders
Credits: Photo Courtesy of EASA [36]

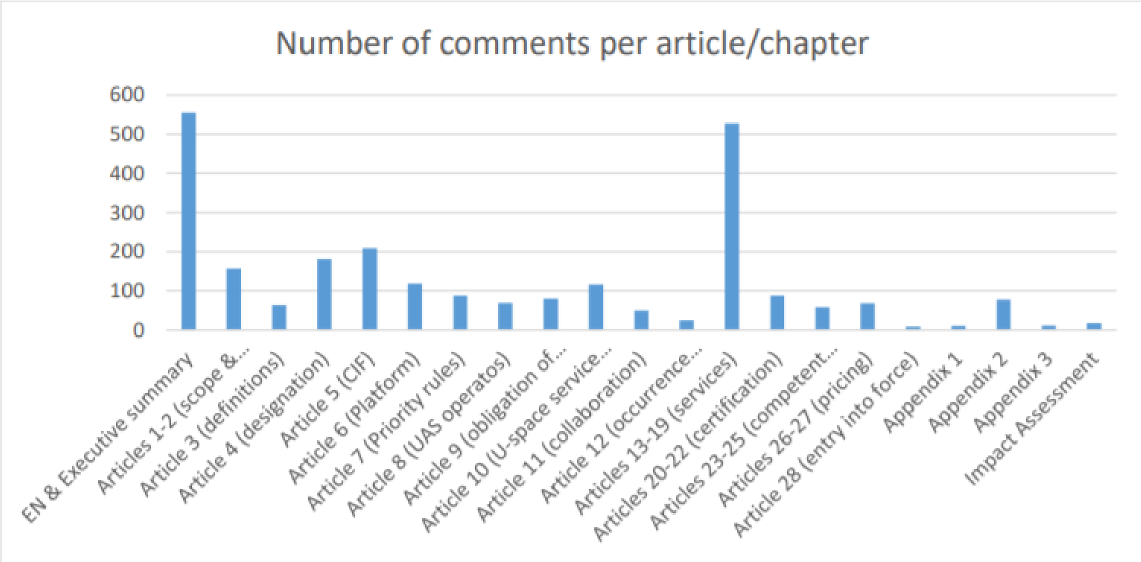


Figure 8: Distribution of the comments received per article
Credits: Photo Courtesy of EASA [36]

2.3 Impacts

The implementation of a united and consolidated airspace, U-Space, will impact drone operators and their operations, existing manned aviation, and relative authorities, and even the common citizen on the ground, both on a regular daily basis and commercially. The regulatory authorities that take care of manned aviation will maintain their existing control over the airspace as it is today, in addition to getting new tasks handled by direct control or delegated to service providers. Such as imposing correct registration and identification of drones, ensure and protect the safety and security of areas deemed critical, and guarantee the privacy, security and safety of citizens, operators, and operations, as well as protecting the environment [31].
For the case of drone operators, U-Space will make the market of drone services open and accessible, in addition to offering everybody access to the airspace that will be open, flexible, and fair, to not exclude anyone independent of drone class and mission. As mentioned before the common citizen will not have their privacy breached and environment disrupted by drone operating in the airspace (visual pollution and noise pollution). However, every citizen will be offered the most innovative and new drone services made available, as well as having their drone operations handled as safely and securely as possible.
As per the business side of the U-Space implementation, it will mean growth in the market and in number of jobs provided through drone operations. It will also support the development of new business models, and further the move towards digitization and automation, which will again create more job and market opportunities [31]. Additionally, the U-Space frameworks supportive and enabling features, such as creating new business models, will push and drive the delivery of U-Space services to conform and adapt to the UAS operators needs. For U-Space Service Providers (USSP) and operators alike, the rule, requirement, and certification processes will be easy to utilize everywhere withing the EU and its member states, because of the unification of the airspace through

U-Space. The European regulation framework also enables the cooperation and equality for EASA or between the different EU member states relevant authorities, when the managing the approval process for USSPs [36].

On the contrary, the U-Space framework is an unfinished concept of operation, this means that the development is still ongoing, and will most likely keep going until it satisfies the requirements on an acceptable level. Even then it will probably continue to develop with new methods, processes, and technologies. However, as per the situation today and in 2020 when [36] was published, development of the concept continues, validation processes for definitions regarding original U-space services are still ongoing. In addition, concept features, communication and technology are still maturing to the appropriate level for when we can validate, make use, and implement them without complications.
Therefore, the early deployment of the first phase stages will only accommodate certain operations that does not rely on a high level of connectivity and/or automation, and the process of deployment from start to finish will take more time than if all the key factors (technology, communication, concepts etc.) were mature enough and available from the starting point. Moreover, to allow the complete deployment of the U-space in the end, amendments will be obtained immediately when made available and the U-Space concept has matured enough [36].
On top of that, if we do not establish a European-wide approach to the UTM subject, [36] say that it could result in implementation of non-interoperable national regulatory systems or non-homogenized application of U-Space. Consequently, because of the contrasting technological solutions and operational strategies, it has a possible safety impact on the unification of UAS operations into the existing airspace and its operations. Moreover, a common approach, such as U-Space approached with a European regulatory proposition, will provide the safety risk attenuating means necessary to effectively integrate management of UAS traffic in every EU member state by having the same regulatory framework and strategies.
The fair competition in such a framework and market would be penalised if no harmonisation is implemented within the EU. European UAS operation and European industry will feel the negative consequences, since they won't profit from the unified recognition framework ensured by EU regulations realization. What's more, is that for UAS operators to be able to operate in the EUs several different U-Space airspaces, they will need to equip their UAS with numerous separate on-board technologies and capabilities which will raise the implementation costs overall [36].
Additionally, EASA has considered that the service market for UASs will be incapable to reach its maximal potential without the integration and harmonisation of the U-Space airspace and U-Space services, since the present times UAS operational and flight authorisations are very problematic to acquire for more advance and intricate UAS operations [36].

2.4 Implementation

When a new system is being implemented, nobody expects it to just be implemented over night and especially not without faults that needs to be fixed, because that is a big risk to the integrity and safety of the existing systems and personnel. This is a self-explanatory reason, as well as others, for when the blueprint for the U-Space framework was first drafted to why it is visioned as being implemented over different phases over time. Additionally, in the blueprint published by SESAR it is explained that the continuous deployment of the framework that comprises the U-Space, is connected to the qualifying technology and blocks of services that will over time be developed and made available and acceptable to implement. As the level of connectivity, meaning that through

data and digital information exchange the advanced environmental interaction forms will be enabled (including unmanned and manned aircrafts), and automation increases, the framework services will evolve parallel with them [31].
The progressive deployment of the U-Space framework is comprised by four different phases: U1, U2, U3, and U4, as seen in Figure 9. Each phase involves a block of UTM services that gets increasingly complex, advanced, and harder to implement. Additionally, the initial timeline for the starting phase of the project is shown in Figure 10, where we see the different parts of the project: Research and Development, Demonstrations and Rollouts.

The first phase stage, U1, is identified as the "foundation services", and is comprised of providing electronic registration (e-registration), electronic identification (e-identification) and geofencing. The drafted blueprint foresee that drone operators has a mandate to register electronically (except if the drone being operated weighs less than 250 grams), this goes for some drone classes in the open category, in addition to all drones in the specific category. Authorities will be able to identify an operating drone and connect it to information saved in the electronic registry. Safety and security requirements, in addition to the law-enforcements strategic plan of action, is supported by the e-identification process [31].
The second phase stage, U2, is identified as the "initial services", and lays the foundations for management of operations, with such services as flight planning, flight approval, tracking, airspace dynamic information, and lastly the interface with existing ATC [31].
The third phase stage, U3, is identified as the "advanced services". It adds services such as capacity management and assistance for conflict detection, to manage more complex operations. It is envisaged that we will see a consequential increase of all types of operations in all types of environments, as a result of automated Detect and Avoid (DAA) capabilities, as well as several new and sound communication means [31].
The fourth and final phase stage, U4, is identified as the "full services" meaning the framework will be complete when this is implemented. The final block of services consists of offering integrated interfaces with manned aviation and the ATC, in addition to the full operational capability of U-Space will be supported with this implementation. However, the U-space framework and drone system relies on a high level of automation, connectivity, and digitization for various features [31].

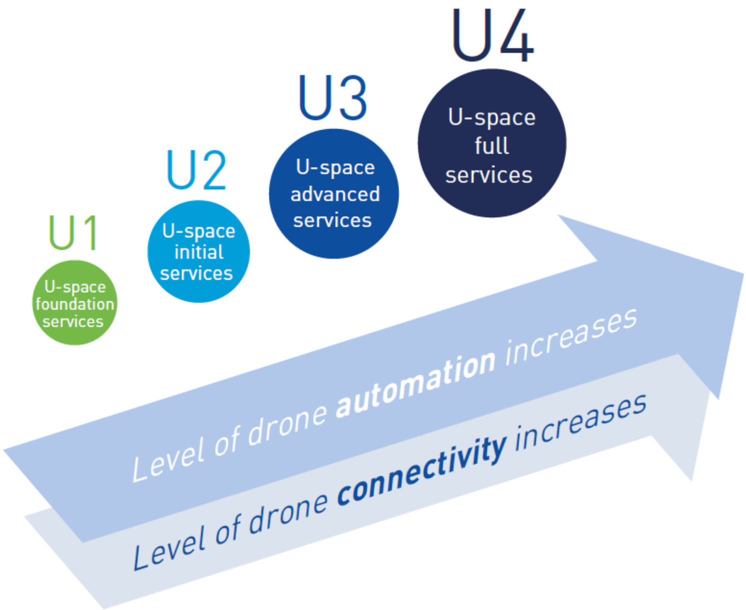


Figure 9: Implementation plan for U-Space
Credits: Photo Courtesy of SESAR [31]

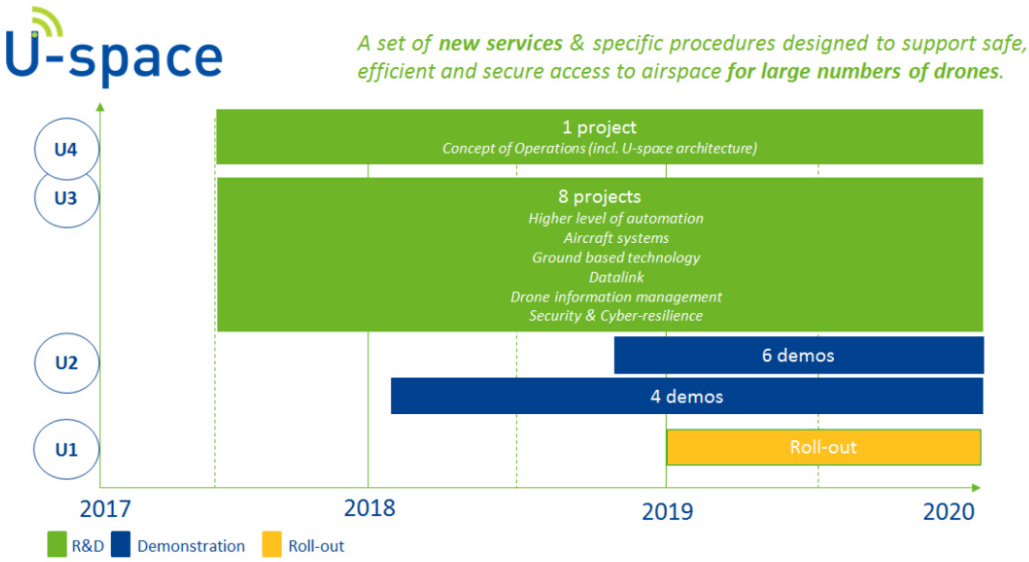


Figure 10: Initial implementation timeline for U-Space
Credits: Photo Courtesy of SESAR

2.5 Situation as per today

In early 2019, the EASA committee voted unanimously on the new regulations proposed by the European commission regarding regulating UAS operations within Europe and [37] wrote that "Commission Implementing Regulation (EU) 2019/94771 [38] accompanied by Commission Delegated Regulation (EU) 2019/94572 [39], defining the technical requirements for drones, were published in June 2019". The Delegated Regulations were instantly applicable, while the Implementing Regulations is being gradually transitioned into, having the completion milestone set in late 2023 to become applicable. Later it the regulations were revised in 2020, to add on two European standard scenarios that permit the utilization of declarations submitted by an operator of a UAS to the national competent authorities. The proposed EASA General concept was accepted and integrated at European level by the regulations mentioned above. This will see to the creation of the three UAS operation categories 'open', 'specific', and 'certified', who depending on the level of risk will have different safety requirements.

Today, as mentioned above drones are separated into different categories depending on their characteristics and the requirements set for them [33]. As of 2020 when [36] was published, the European Parliament and Council have accepted the complementary additions and changes to the Basic Regulation which adapts the extent of the EASA system to apply for all UAS categories and sizes. This has led to a new set of rules for safe operations in the 'open' and 'specific' UAS categories, which was drafted in 2019, being accepted by the European Commission. There are some foundational elements in the regulations regarding the 'open' and 'specific' UAS categories, that facilitates the development of several U-Space mandatory services, such as e-registration, e-identification, and geo-awareness. Furthermore, essential data for the U-Space functionality is starting to be provided by creation and installation of defined geographical zones by some selective EU member states.
Current data on VLOS suggest that the number of applications for authorisation of UAS operations have exceeded the number of the manageable approvals and has created a need to streamline the approval system through the development and continuous development of standard scenarios and predetermined risk assessments constructed from the available experiences from various nations that is mature enough. Also, the authorization of some types BVLOS operations which are more complex, will call for restrictions of the airspace such as dividing the airspace to be able to minimize the risks. Hence, why there has not been more BVLOS operations in the European airspace as per today, since measures to minimize airspace risks for BVLOS operations are complex and takes time in addition to wider consultation of the concerned stakeholders [36].

A number of European member states, such as France, Italy, Poland, Switzerland, Finland, and Spain, have taken the initiative to start working on initial U-space services, basic services such as geo-awareness and flight authorisation. The initiatives are sometimes related to U-space demonstration projects from the SESAR programme and sometimes not related to SESAR at all, either way the initiatives does not always qualify for entering the deployment stage. The initiatives are not considered to be a part of the harmonised U-space solution, at least not yet, since there are clear differences in approach, extent and standards being applied [36].

The first phase stage of deployment of U-Space, who was supposed to begin its rollout in 2019, should have the "Foundational Services" completely deployed, as the second phase stage for the "Initial Services" begin in 2021 before supposedly being in place at the end of 2025. The first phase stage regarding e-registration, e-identification, and pre-tactical geofencing. However, saying the deployment of the first phase stage is finished does not mean that it is perfected, it will be

continued to be developed and evolve along the way to the complete framework is finished. Even then, it might continue to develop.
Moreover, since we are past the deadline for rolling out the first phase stage, we should be starting to see phase stage two access to services such as flight planning, flight approval, tracking, airspace dynamic information, procedural interface with ATC, tactical geo-fencing, emergency management, monitoring, strategic de-confliction. According to the roadmap of U-space, we begin the deployment of the third phase stage in 2025, when the second phase stage end, and supposedly we should then begin see the rollout for services such as Dynamic Geo-fencing, Collaborative interface with ATC, Tactical De-confliction, and Dynamic Capacity Management, until the deadline in 2030 (or later) [36].
For drone operations in the 'open' and 'specific' category the first EU regulatory framework is currently (early 2022) in place, and according to the European Plan for Aviation Safety [37] the next thing to focus on is to "successfully implement the EU's 'U-space' regulatory package" and to facilitate UAS operations in the 'certified' category (including urban air mobility applications) by complementing the regulatory framework already in place.

There is obviously a technological gap to be filled before realization of the U-Space concept is made feasible. Communication, which is a key element for the operation of U-Space, already exist in many forms used and specified for different purposes, but a communication method optimal for UTM/U-Space is not yet specified. In an overview made by SESAR for potential new technologies for U-Space [40], several communication solutions exist that can be utilized. Many are just not acceptable for the level of quality and reliability that is required in the U-Space system, on the other hand some solutions as e.g. 5G are more promising, but not yet developed enough to fulfil its potential. Additionally, several of the services required in the U-Space system are not yet acceptable, but in continued development to perfect the services to an optimal and especially an acceptable level. E.g. geo-fencing has shown great potential and has been tested under safe circumstances, but to integrate it into a harmonised system it needs to be optimised for smooth operation in a "symbiotic" system to the benefit of every user and entity in the U-Space airspace.

As opposed to manned aviation, COVID-19 have thus far not had any remarkable impact on the development and operation of UAS. Many frameworks on the conceptual level, platform architectures, methodologies, and practical demonstrations are continuing their development at a fast pace in several member states across the EU. Actually, it is reported that some use cases of drones, such as delivering samples in the medical sector, delivering vital provisions to medical personnel, humanitarian aid, and emergency/disaster response, are being accelerated by the COVID-19 crisis. Additionally, in the years to come EASA will continue fostering the development of the European drone ecosystem, as a part of the contribution to the European Commission's 'Drone Strategy 2.0'. The support will come through the further development and aiding the several member states' integration of a regulatory framework described as common operations-centric and risk based, that will address expectations from the society related to cybersecurity, environmental preservation, and safety [37].
A continuing high-priority activity for EASA is the facilitation of the safe implementation of the up-and-coming novel market segment of UAS, which is rapidly evolving and largely unaffected by the ongoing COVID-19 pandemic. Supporting the member states and the industry in the expected implementation of the various new and old U-Space services, is considered an additional focus point in the next phase for EASA. Furthermore, the emerging Counter-UAS action plan will be continued to be worked on as EASA complete specific ongoing tasks, by engaging in the accessing the risks from the unsanctioned operation of drones [37].

The counter-UAS action plan and the need for it emerged recently after an incident at Gatwick Airport in December 2018. The incident highlighted the need for support to aerodrome operators, ATS providers and aircraft operators, by helping to minimize the operational disruptions as a result of preventing and handling unsanctioned drone operations in the aerodrome environment. Unsanctioned drone operations are something not all European airports are properly prepared for, hence [37] described guidance documentation as needed on "how to set up a drone incident management process, and how to best clarify the roles and responsibilities of the different actors with an active role during such incidents". Additionally, occurrence reporting requirements is also considered necessary to create clarity in relation to situations of unsanctioned drone operations, as well as an overview of all the counter-drone technologies (detection, tracking, classification, and neutralisation of unsanctioned operating of drones).

Therefore, EASA have proposed to play the part of European coordinator for an action plan encompassing five elements and to cooperate with the stakeholders that are affected (specifically member states, aerodrome operators, aircraft operators, ANSPs, EUROCONTROL and the European commission), for the purpose of avoiding an assorted mix of different measures implemented by various nations. All for the purpose of complementing EASA's establishment of various regulations for U-Space. The plan was to establish a Counter-UAS action plan that is subjected to periodic review and revision, and thus we saw the publication of the latest and third issue of the action plan in late 2020 (plan and objectives presented in Figure 11), with several amendments as the realization progresses. The five elements of the Counter-UAS action plan can be viewed below [37].

#	Objective	Deliverable	Timeline/ Status
1	**Educate the public** to prevent and reduce misuse of drones around aerodromes	1.Safety promotion material to create public awareness and understanding of the existence and purpose of geographical zones https://www.easa.europa.eu/sites/default/files/dfu/easa_printmotif01_version005.pdf; https://www.easa.europa.eu/document-library/general-publications/infographics-drones 2. AMC & GM defining a common unique digital format for UAS geographical zones.	1. Completed 2. In progress
2	Prepare **aerodromes** to mitigate risks from unauthorised drone use	EASA guidance material (in the form of a manual) describing the roles and responsibilities of the actors, and best practices on how to respond to unauthorised drone operations in the surroundings of an aerodrome: https://www.easa.europa.eu/sites/default/files/dfu/drone_incident_management_at_aerodromes_part1_website_suitable.pdf	Completed
3	Support the assessment of the **safety risk of drones** to manned aircraft	Paper (Input to Objective 2) addressing the consequences of drone collision with manned aircraft	In progress
4	Ensure that **C-UAS measures** are swiftly considered and implemented from a global safety perspective	Contribution to the development of International Standards to support the safe and harmonised implementation of Counter-UAS Systems into an airport environment and ATM/ANS systems	In progress
5	Support adequate **occurrence reporting**	1. Define high-level criteria to classify airprox events. 2. Evaluate compatibility of existing occurrence reporting procedures for inclusion of occurrences involving UAS. 3. Develop a suitable action plan to integrate UAS in common occurrence reporting procedures.	1. In progress 2. In progress 3. In progress

Figure 11: Objectives of the Counter-UAS action plan
Credits: Photo Courtesy of EASA [37]

Another focus point highlighted in the European Plan for Aviation Safety [37] is global interoperability, civil-military collaboration, and the ability to concord with other regions' strategy plans (e.g. the Federal Aviation Administration NextGen), comprise a fundamental part of EASA's continued work. Furthermore, supporting and providing what's necessary to incorporate the required operational changes needed to accomplish SESAR's vision of a single harmonised European sky. Additionally, SESAR's continued research and development work and Airspace Architecture study will be taken into consideration when establishing new regulations and rules. The work and studies is based on virtualisation and ATM data as services (allowing a more flexible supply of ATM services through virtual centres and a common data layer), dynamic airspace management (enabling dynamic grouping and de-grouping of specific branches and handling staff resources appropriately), capacity-on-demand agreements (temporarily delegate supply of air traffic services to an alternative centre with spare capacity to facilitate more dynamically the continuity of the air traffic services), and operations based on trajectory (facilitating operators utilizing their preferred flight trajectories in the airspace).

Incorporating aiding activities that enable the achievements of operational improvements and innovative ATM operational concepts, will be considered by EASA. The procedure of implementing the necessities should be considered by the previously mentioned activities in an extensive way, enabling safe, secure, and interoperable implementation of the needed solution in a cost-effective way. These solutions may extend to 'enabling infrastructure' that includes solutions such as global navigation satellite system, satellite communications, and other satellite-based communication, navigation, and surveillance solutions or other up and coming solutions in the telecommunication sector [37].

In a publication on the Norwegian government website [41], they write that in a preliminary assessment done by the Civil Aviation Authority, that they are positive to the Regulations proposed by EASA and deemed it advisable to incorporate into Norwegian aviation law through the European Economic Area (EEA) agreement and that the assessment done is supported by the Norwegian Ministry of Transport. Both the Civil Aviation Authority and the Ministry of Transport has deemed it important that Norway joins the initiative of a standardised and harmonised European regulation framework about how automated integration of drones will transpire in airspace with dense traffic and activity.
On the website it is pointed out that the application of the regulations does not force any obligations on the state to establish U-space airspace at all or within a certain deadline. On the other hand the Regulations demand that if the state is to provide the services described within the regulations, it must be complying with the demands and requirements set in the regulations. Moreover, it is also pointed out that the expectations for the drone market would suggest that Norway should not postpone the implementation of the measures set by the regulations [41].

3 Technical Framework UTM

The proposed U-Space Architecture has to follow and support a certain set of principles as a foundation to the complete picture. In [35] the purpose for developing the standards for CORUS architecture is to help defining a Concept of Operations and consequently supplying a fundamental layer for the entire U-space system. It is also mentioned in the documents that the entire overview and views of the CORUS architecture project is not mentioned but is meant to be accessed in the European Air Traffic Management Architecture (EATMA) internet portal (if you have gained the right to the access it), however the main strokes are reviewed. The architecture is described by CORUS [35] as:

- **Safety Focused:** The different parties, people, and places that might be affected by the U-space operations, shall always be taken into consideration when the architecture addresses safety.
- **Securely Designed:** To follow the SWIM principles, the architecture shall address several security issues, for example encryption needs, stakeholder authentication, cybersecurity, and consequences.
- **Service Oriented Architecture:** To guarantee that the solutions are created with a foundation of a certain set of services with common characteristics, the architecture shall have a service oriented approach.
- **Modular:** The architecture shall be able to be broken down into different functional blocks, each containing a purposeful set of functionalities with the required outputs/inputs, that can be replaced or reused.
- **Standard-based:** Defining and having a base on open standards is a requirement for the interfaces, whenever there are exchanges between roles.
- **Interoperable:** The main purpose of the interoperability is to enable corresponding and non-discriminatory regional and global drone operations.
- **Incremental approach:** Building upon the previously combined baseline, making the architecture work an iterative and incremental process.
- **Allowing variants:** The principles set are to ensure the interoperability between several implementations; thus the architecture work shall allow variants and alternative solutions to be described.
- **Automated:** The development of the architecture work shall be with the purpose enabling the delivery of safe and secure U-space services with a high degree of automation, to the purpose of relieving manual operations of labours considered too exhaustive.
- **Open:** A components-based architecture system shall be developed and to make upgrading, including, or changing components effortless during the system's lifetime, it should rely on standardised or published interfaces. Reducing risks, improving interoperability, increasing flexibility, enable reuse, reducing time and costs of marketing, and encouraging competition are some of the other expected advantages of an open architecture system.

- **Technology agnostic:** Through allowing independent platform design, the architecture shall be detailed independently of any future implementation specifics (e.g. operational architecture shall be consistent through elements like platforms, programming languages and specific products).
- **Deployment agnostic:** In accordance with the established business and regulatory framework, the architecture work shall not be constrained by different choices of deployment.

The principles listed in [35] (as seen in Figure 12) does not imply any weighing of importance for the architecture and are phrased to substantiate that any suggested service meets the requirement for insertion as a service [35]. It is based on the list of architecture characteristics above and drives any implementation of U-Space architecture.

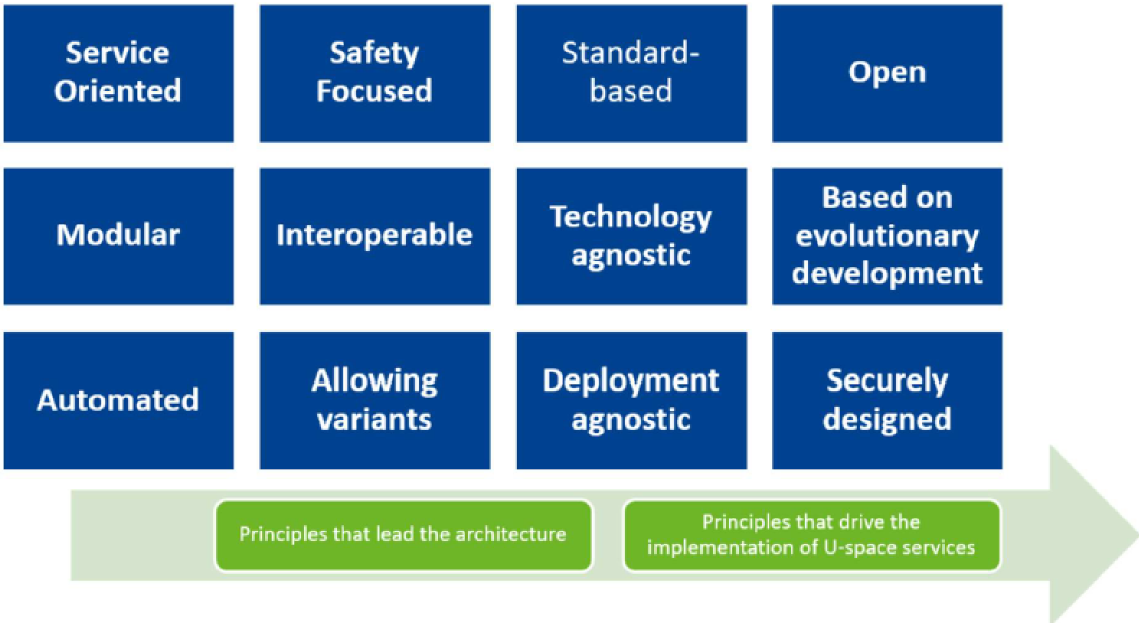


Figure 12: Principles driving U-space architecture
Credits: Photo Courtesy of CORUS [35]

1. **Safe**

   The service is tailored to mitigate the risk to third parties on ground level, other airspace users, and passengers. Qualified system management processes and systems supports the services.

2. **Reusable**

   Other U-space services can use the services, in addition to the services having the ability to be used in several other and different operational scenarios.

3. **Autonomous units of business functionality**

   The service provides a business function that might be independent of other services.

4. **Contract-based**

   Standardised interface service contracts strictly describe the policies and interface.

5. **Loosely coupled**

   The independence of the service realization is a key point when tailoring the service contract.

6. **Platform-independent**

   Any platform that aids the service transport and interface requirements, should have the option to accommodate both the service and consuming systems.

7. **Discoverable and location independent**

   The service might move over time without interfering with consuming systems through location placement by virtue of a discoverable service catalogue/registry and obtained through universal resource locators.

8. **Accessible**

   The service is accessible for everybody, available to the public for direct use, and has public/semi-public interfaces for use by third party application. The exception of incidents of security breaches, the level of security being defined by regulation and/or standards.

9. **Interoperable with ATC**

   In order to mitigate the impact on ATM, all data related to U-space, that is sent to ATC, shall be complying to ATC requirements (including certification of information and cybersecurity as requested by the ATC system), due to the emergence of U-space.

10. **Auditable**

    If requested, the logged real-time data and recordings shall be made available for investigation intentions, as well as authorized authorities can on a national/European level monitor and audit the service performance. In addition, if the anonymization/obscuring criteria are met, authorities have the option to provide the selected data for research, system development and training purposes.

11. **Liable**

    The service shall be tailored in such a way that makes it possible and easy to determine who is responsible for any incorrect and/or untruthful data sharing or service failure.

12. **Data validity**

    The data integrity and validity shall be upheld in their required timeline, this will be guaranteed by the service design.

13. **Performance based**

    The service providers have to meet certain criteria regarding the services they provide, it has to be of a certain performance level according to authorities, it has to be robust with built in security and safety measures (e.g. filtering to guarantee that the subsystems only deal with important data and no single point if failure). In addition, the latency of a service response has to be within a certain required performance level, as well as the service being of a quality that is in accordance with a Service Level Agreement. Lastly, it has to be delivered according to the reasonable time constraints.

14. **Automated**

    To facilitate high-speed response and guarantee low costs, the human intervention is to be minimized through the service having a high level of automation. Humans are to intervene upon exceptions or when incidents of unlawful or hazardous operations are highlighted by the automation, in addition to implement policies, monitor alerts/limits provided by the automation.

15. **Standard-based**

    The use of standards that are within reason of the nature of the service being provided, shall be a key focus point when tailoring, integrating, and consuming the service.

16. **Secure**

    Cybersecurity and guarantees of strong authentication of all stakeholders are main traits of the service.

17. **Sustainable**

    The mitigation of unmanned aircraft operations privacy protection for citizens and environmental impact, when and where possible, (including noise) are to be taken into consideration when designing the service.

18. **Scalable**

    The service is tailored to scale in several different ways, including (but not restricted to) the number of services or users, the number of simultaneous flights, the number of business cases supported, the geographical areas where U-space is deployed. Anything regarding specific national or regional design of a service, should be changeable and parametrized, and the more generic the service set-up is, the better.

CORUS have coordinated their efforts with SESAR Joint Undertaking and the EATMA team to establish and advance the architecture description using EATMA technology, framework, and methodology. The new structure of the EATMA model is based on the North Atlantic Treaty Organization (NATO) Architecture Framework (V3) [35]. Additionally, CORUS, being the responsible entity for delivering the Concept of Operations for U-space, has to develop a high-level architecture for the U-space concept and also take into consideration other relevant project's U-space architecture, hence CORUS aligns and integrates the structuring and architecture work into a united architecture, as a part of the architecting process for the U-space Architecture.
To make it possible to establish a model of the architecture that allows traceability from technical solutions to performance needs, how the different elements are related to each other is defined in the EATMA framework.

3.1 Architecture layers and elements

The framework from EATMA categorizes its views and elements into layers, which there are six of, and the aim of the layers is to differentiate as well as compile the elements of the U-space architecture through natural division into layers. The layers are a combination of different sets of elements which provides the description of the complete view of the project.
The listed layers are described by CORUS in [35]:

- **Programme layer**

  This layer is described as the programme layer and contains the facilitators and the Operational Improvement Steps as elements that is implemented to describe the U-space deployment schedule and gives solutions and their implementation protocol through a project management point of view.

- **Capability layer**

  This layer is the capability layer and is acknowledged as the strategic layer, where the U-space's abilities are explained in detail.

- **Operational layer**

  This layer is the Operational layer where the operational concepts are explained through numerous elements, which contain several models of processes and details of how U-space actors amalgamate.

- **Service layer**

  This layer is the service layer where services are described to work as a connector between the technical solutions and the operational need. In addition, this might contain the connections to data elements.

- **System layer**

  This layer is the system layer where all the technical and human assets of a U-space system are described, including the U-space systems interactions with the surrounding systems and its internal functional breakdown.

- **Standards layer**

  This layer is the standards layer where the regulations and standards need within the European ATM is described.

In [35] CORUS states that the architecture of the U-space concept mainly concentrates their efforts on four of the layers (as presented in Figure 13), with the aim of supplying elements to establish the concept of operation: **Capability, Operational, Service and System**.

Figure 13: EATMA layers structure
Credits: Photo Courtesy of CORUS [35]

The different layers are composed of subsets of elements that is utilized for the development of the Architecture. The elements of the focus layers are:

- **Capability layer:**

  This layer handles the business side of the architecture and explains the abilities the structure is capable of.

- **Operational layer:**

  This layer contains elements that comprise the operations, such as Nodes, Activities, Information exchange, Information flow and Information elements.

- **Service layer:**

  This layer contains the elements that are the several services provided and utilized.

- **System layer:**

  The system layer contains the elements Stakeholders, Capability configuration, Technical system, Functional blocks, Roles and Functions.

3.2 Capability Architecture

The capability layer is acknowledged by CORUS to be the strategic layer of the structure, that represents the capabilities/business services and details the performance measures and abilities of the U-space concept, for example the validation targets and validation results. Since capability is one of the main focus points of the U-space architecture structure, it is explained with several definitions to really get an understanding of what it means.
In [35], the ability of one or several projects' resources to supply a certain type of procedure or a certain type of effect to the projects stakeholders is the capabilities of the project(s). It also defines a capability as something that can illustrate an entire project through the capabilities it possesses, hence it stands for a precise description of one or more abilities of a project. Additionally, a capability is unrestrained from "considerations of physical organisation or specific choices of technology", based on the idea that a capability is a declaration of "what" that is to be executed and does not have reference to "how" or "by whom" they are executed by.

'Capabilities' is a valuable business idea that details a project's capabilities or expertise. Normally they alternate as a reaction to a calculated drive or change but alternates seldom and are quite unwavering as opposed to processes, roles, and functions of a project, which may alternate repeatedly. They might be charted back to calculated objectives and goals, in addition to being a supplier of an advantageous starting point to acquire subsidiary level components such as technology and applications, functions and process resources.
The Complete U-space project is detailed by The Capability Model, which is a set of fragmented capabilities and their interconnection with ICAO, seen in Figure 14.

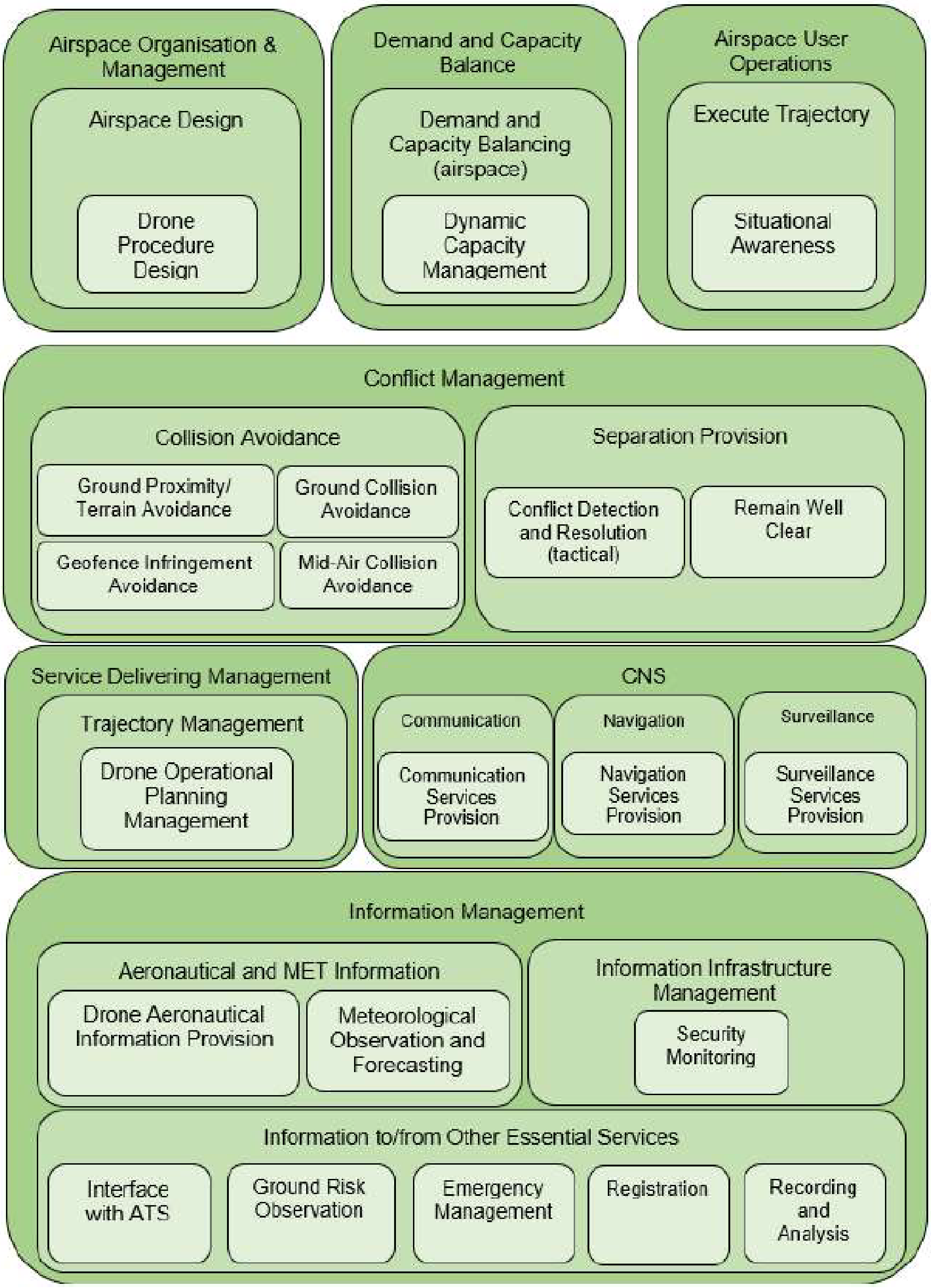


Figure 14: The U-space Capability Model
Credits: Photo Courtesy of CORUS [35]

Each of the multiple capabilities in The Capabilities Model was given an explanation by CORUS. These are:

- **Drone Procedure Design:** When a drone operation might interfere with other operations, there is created a set of measures that lets the Drone operation interface with ATC to guarantee comprehensible and distinct drone operation, in addition to making sure that the drone operators and the ATC exchange the necessary information. This will facilitate the opportunity for drones to utilize and operate in controlled airspace and near airports, with more flexibility and measures based on rules that are agreed upon to approve or reject operation.
- **Dynamic Capacity Management:** This is the expertise necessary to catalogue and handle access to the airspace when new requests are proposed, in both official and unofficial situations, in addition to setting the volume limit and monitoring the desire for airspace.
- **Situational Awareness:** This capability ensures the correct and necessary exchange of traffic information to user situational awareness, based on monitoring.
- **Conflict Detection and Resolution (tactical):** This is the ability that guarantees safe separation when flying through detecting and resolving conflicts throughout the tactical stage of operations.
- **Remain Well Clear:** To avoid conflict, ensuring a safe distance between the relevant unit and other units is a required capability.
- **Ground Collision Avoidance:** The ability to avoid crash incident with parked and non-parked aircraft throughout taxi or push-back or on the runway/landing space or while one is grounded and other entities in the air comes close to the ground.
- **Ground Proximity/Terrain Avoidance:** This capability is the ability to avoid collision with the terrain or objects on the ground, while being airborne but close to the ground.
- **Geofence Infringement Avoidance:** The ability to avoid infringement or entrance of unauthorized vehicles into geofence zones, which is predefined volumes of airspace that are meant to be either stay in or out of, constituting the drone aeronautical information.
- **Mid-Air Collision Avoidance:** The ability to avoid collision between operating airborne vehicles.
- **Interface with ATS:** Interoperability between the drone operator and the ATC that includes measures that guarantee appropriate and efficient cooperation when utilizing the U-space services for drone operations that interfere with the existing ATS.
- **Registration:** Following the Regulations, a drone operator is required to provide the necessary and relevant information on the operation, the drone, and the pilot to the relevant authorities through registration.
- **Emergency Management:** The ability to manage solutions for emergencies in U-space, this also contains the interchanging of appropriate information between the pertinent actors and drone auto-diagnosis.

- **Ground Risk Observation:** Providing the necessary information, both static and dynamic, about risks on the ground (e.g. population density, obstacles and terrain in elevated positions and other ground traffic such as cars, trains, and vessels) that may impact drone operations at the scale of interest of small drones.
- **Recording and Analysing:** The ability to log incidents and relevant events through U-space recording, comprised of playback for incidents, logbooks, accident investigations and legal recordings, for the purpose being able to supply statistics, reports, and playback.
- **Security Monitoring:** The ability to fend against attacks on the data (coordination between the relevant unit and other vehicles and infrastructures) and vehicle's information technology and communications systems.
- **Drone Aeronautical Information Provision:** The capability to provide manned and unmanned operators, relevant to U-space, with the aeronautical and logical information, which includes available aeronautical information or predefined regulated areas.
- **Meteorological Observation and Forecasting:** The capability to provide information about the state of present and incoming weather in the airspace that presents a risk to U-space and ATM.
- **Surveillance Services Provisions:** Tracing and fusing for determining positioning information about an aircraft, enabled through the provision of air and ground surveillance data collected from several independent sources.
- **Navigation Services Provision:** Having the capability to enable (supplying the monitoring, the link and the coverage provided) the recording, planning, and controlling the motion of an aircraft from a starting position to a certain destination.
- **Communication Services Provision:** Having the capability to enable (supplying the monitoring, the link and the coverage provided) ground-ground, air-ground, and air-air communication.
- **Drone Operational Planning Management:** The ability to take all appropriate information into account when managing the planning of a drone operation, such as applicable rules, aeronautical information, traffic information and meteorological information.

From the U-space Roadmap services, CORUS developed the capability model and its capabilities. The mapping between the services and the capabilities can be viewed in the appendix.

3.3 Operational Architecture

In the Operational layer, the operational concept is described by CORUS [35] through different components, hence it is independent of any physical implementation. The description of how all the components and actors coordinates and cooperates with each other.
The components that are focused on in the operational layer are:

- **Node**, which is a logical unit that execute tasks and represents different actors that interacts with each other through information exchanges.

- **Information exchange**, that is the process of exchanging information elements between nodes, where the type of information elements that are exchanged and whom the exchange is between are defined. This is highlighted as an important element to be realized of the Operational layer.
- **Activity**, this is a logical procedure that describes the execution of different tasks and defines the things that are required to be completed to conclude a capability. Nodes and Activities are logically grouped together and therefore consequently related to the executors of nodes, the stakeholders. Aspects of activities may be automated and performed by utilities (e.g. Services and Functions) that is supplied by Technical Systems, in addition to the fact that activities can be implemented by people,
- **Information flow**, which is quite frankly describe by CORUS as "a flow of information from one Activity to another", and additionally categorizes the information elements that are sent between nodes. The information flow is established as a one-way interaction from one node to another but can be gathered together to form more complex two-way interactions.
- **Information element**, is a conventional way of representing information that gets exchanged between nodes in information exchanges.

CORUS has created a diagram of all the main node interactions and a list of the nodes with descriptions that can be viewed in the appendix. In addition to several example use cases in [35].

3.4 Service Architecture

Services are the connector between the operational need and technical solutions, and these services are described in the service layer. The paper [35] has defined a service as "The contractual provision of something (a non-physical object), by one, for the use of one or more others". The foundation of a service is built upon the interaction between a customer/consumer and supplier/provider, it can be executed in several forms as for example voice communication or digital form of data exchange or formulated procedures and processes. Services are highlighted as essential when describing the relationship between the several and different architectural characteristics and reaching full specification of a service starts with identifying the service.
When categorizing services, they are split into U-space services and U-space supporting services mainly (presented in Figure 15), where:

- **U-space services**, are services that are related to the U-space domain among USSPs and for the consumer. Additionally, they can be split further into the categories Principal U-space services and Operational U-space services when sorting based on the responsibilities in the deployment architecture.
- **U-space supporting services**, are services not necessarily specific for U-space, but more like services that supply more general data from other sources that can be utilised by other services, such as terrain, obstacles, surveillance, cellular coverage, and weather. These services may also be separated into the groups Infrastructure Data Services and Supplemental Data Services.

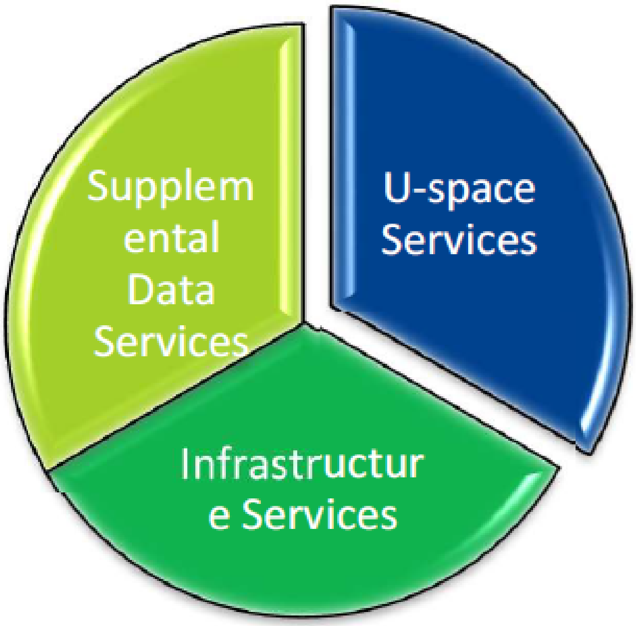


Figure 15: Typical split for service categories
Credits: Photo Courtesy of CORUS [35]

CORUS have included an initial set of services in the three main categories (presented in Figure 16, 17 and 18, for U-Space, Supplemental Data, and Infrastructure services), but already by the publication of [35] stated that this list of services is not finalised and that they have already identified several additions to make to both the architecture and regulations. In addition, as the development progresses and specification activities may result in optimisation to merge, split and/or introduce new services as the needs require. Moreover, the initial comprised list of services is based on the traceability with the U-space Capability Model and the Operational process Model of the Operational View, by experts.

U-space Service	
Registration *Drone Registration* *Drone Pilot Registration* *Drone Owner Registration* *Drone Operator Registration*	The service (one service or many for the specific registration entrytype) to interact with the registrar in order to obtain registration. It mainly includes service operations to request a registration, maintain registration information and cancel an entry.
e-Identification	The identification provides access to the information, where necessary complemented by the one stored in the registry, based on an identifier emitted electronically by the drone. The identification service includes the localisation of the drones (position and time stamp).
Tracking	The service to receive location reporting and to fuse and provide tracking information about drone movements
Drone Aeronautical Information Publication[5]	The service to access to drone aeronautical information (whole or its subparts -e.g. geographical subsection)
Geo-Awareness	The service to provide awareness of airspace limitations depending on the privileges of the drone operator. It is as well providing detected potential breach of airspace limitations and alerts.
Geo-Fencing provision	The service to support geofencing ondrone capability, which shows where it is possible to fly or not according to the authorisation of the drone, operator and latest drone aeronautical information.
Drone operational plan processing	The service to access to the flight plans, to submit new plan and modify/cancel alread existing ones. The service to manage authorisations workflows where necessary and the permissions with relevant authorities.
Strategic Conflict Management	The service to check for possible conflicts in strategic phase for a specific flight/mission plan/intent. It as well provides resolution advisories.
Tactical Conflict Management	The service to check possible tactical conflicts for flights including the provision of resolution advisories.
Monitoring	The service to provide monitoring alerts/warning about the progress of a flight (e.g. Conformance monitoring, Weather compliance monitoring, Ground risk compliance monitoring, Electromagnetic monitoring)
Traffic Information	The service to provide whole set of information required to obain a situation awareness.
Interface with ATC	Even if identified services are already providing means to achieve the interoperability with involved ATSUs or ANSPs as well e.g. to exchange tracking/traffic information, drone operational plans, emergency information, the interface with ATC service is to realize the collaboration with ATSUs in managed airspace for establishing the contact with the drone, e.g. asking/forwarding clearances (similarly to the Controller Pilot Datalink Communication for drones).
Emergency Management	The service to detect, to notify and to alert about emergency and to activate mitigation scenarios/actions.

Legal Recording	The service to record legal information for incident/accident investigation or suitable for statistics.
Dynamic Capacity Management	The service to balance traffic demand and capacity constraints.
Registration Assistance	The service to support the registration process to aid the submission of registration information.
Drone operational plan preparation assistance	The service to support the operator to guide the fileing of a flight /mission intent/plan.
Risk analysis assistance	This is a supporting service to elaborate specific operation risk analysis. Escalation to Supervisor for exceptions.
Accident / Incident reporting	The service to prepare and submit an accident/incident report and to mange its lifecicle.
Citizen reporting	The service to be used by the citizen to inform the law enforcement about not cooperative drone traffic or other suspicious event to be reported.
Digital Logbook	The service to create and keep up-todate the digital logbook

Figure 16: U-space Services and their descriptions
Credits: Photo Courtesy of CORUS [35]

Supplemental Data Services	
Weather information	The service to collect and present relevant weather information for the drone operation. This include hyperlocal weaher information when available/required.
Geospatial information service • **Terrain map** • **Buildings Obstacles**	The service to collect and provide relevant Terrain map, buildings, obstacles for the drone operation.
Population density Information	The service to collect and present relevant density map for the drone operation.
Electromagnetic information	The service to collect and present relevant electromagnetic information for the drone operation.

Figure 17: Supplemental Data Services and their descriptions
Credits: Photo Courtesy of CORUS [35]

Infrastructure Services	
Navigation Coverage information	The service to provide information about the navigation coverage. It can be specialised depending on the navigation infrastructure available (e.g. ground or satellite based). This service is used to plan relying on required coverage.
Navigation Infrastructure Monitoring	The service to provide status information about navigation infrastructure. This service is used during operations.
Communication Coverage information	The service to provide information about the communication coverage. It can be specialised depending on the communication infrastructure available (e.g. ground or satellite based). This service is used to plan relying on required coverage.
Communication Infrastructure Monitoring	The service to provide status information about communication infrastructure. This service is used during operations.
Surveillance Data	The service to detect traffic and to provide relevant tracks. (e.g. antidrone or telecom service provider by triangulation).

Figure 18: Infrastructure Services and their descriptions
Credits: Photo Courtesy of CORUS [35]

In the Concept of Operations Annex K, CORUS writes that according to EATMA there is a need for tracing the identified services to the Capability Models capabilities, since a service is a measure to fulfil a capability. Therefore, CORUS have set up a table mapping all the services to the different capabilities, which can be viewed in the appendix.

3.5 System Architecture

All the interactions with other environmental networks, the technological and human assets, and breakdown of the internal functions within a SESAR system is described in the system layer. Within these systems there are elements and/or nodes that drives and/or helps the system, such as:

- **Capability Configuration**, is where a Capability is acquired from observing a stakeholder's type of business and/or operational need(s). To elaborate, this comes as a result of amalgamation of Roles and Technical Systems that consequently comprises a Capability Configuration.
- **Functional Block**, is the result of the connected and rational assembly of automated functions in a Technical System.
- **Technical System**, is comprised of Function Blocks and is the man-made system that constitute the technical segment of Capability Configurations. In addition, Services are the describers of the interactions between technical systems.
- **Stakeholders**, are the people, teams or organisations that has concerns related to or involvements in a project (e.g. European ATM). Specifically, the concerns and involvements are regarding the operation, the progress or any other aspect of the project that is important or critical in any other way to a single or several stakeholders.

- **Roles**, are the facilitating factor of a person or an organisation that fulfils a certain function and may be represented in both the system and operational layer of the architecture. For the Operational layer, a role represents the need for a role to perform a certain function, as well as representing a human resource in a Capability Configuration.

CORUS [35] has identified and specified the initial set of stakeholders, presented in Figure 19. Moreover, they state that it is expected that in the future with a more complete and finalised U-space system and structure, the appropriate information will be possible to access to the stakeholders at the right time (conceptually thinking of an information manager for the entire U-space system). In addition, they have included a list of explanations for the several stakeholders including some not mentioned in the diagram, as well as the different roles, which can be seen in the appendix.

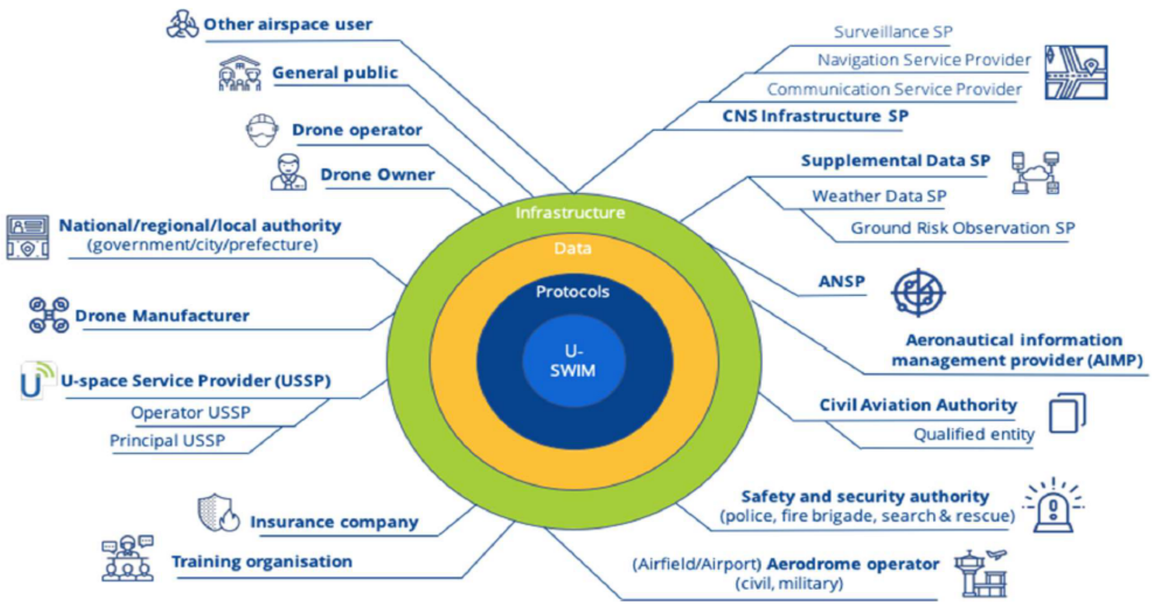


Figure 19: Stakeholder roles using U-space services
Credits: Photo Courtesy of CORUS [35]

3.6 The framework architecture we are going to use

The Architecture made by the Swiss government (structure, departments and links presented in Figure 20) seem like a good fit for utilization on the Norwegian continental shelf and by the Norwegian government, mainly because the system is modelled to abide the strict criteria for safety, efficiency, equity, security, and scalability. All while supporting the relevant authorities' roles and responsibilities of governing the USSPs for centralization purposes, and additionally it offers the market of services and data with high regulatory flexibility.

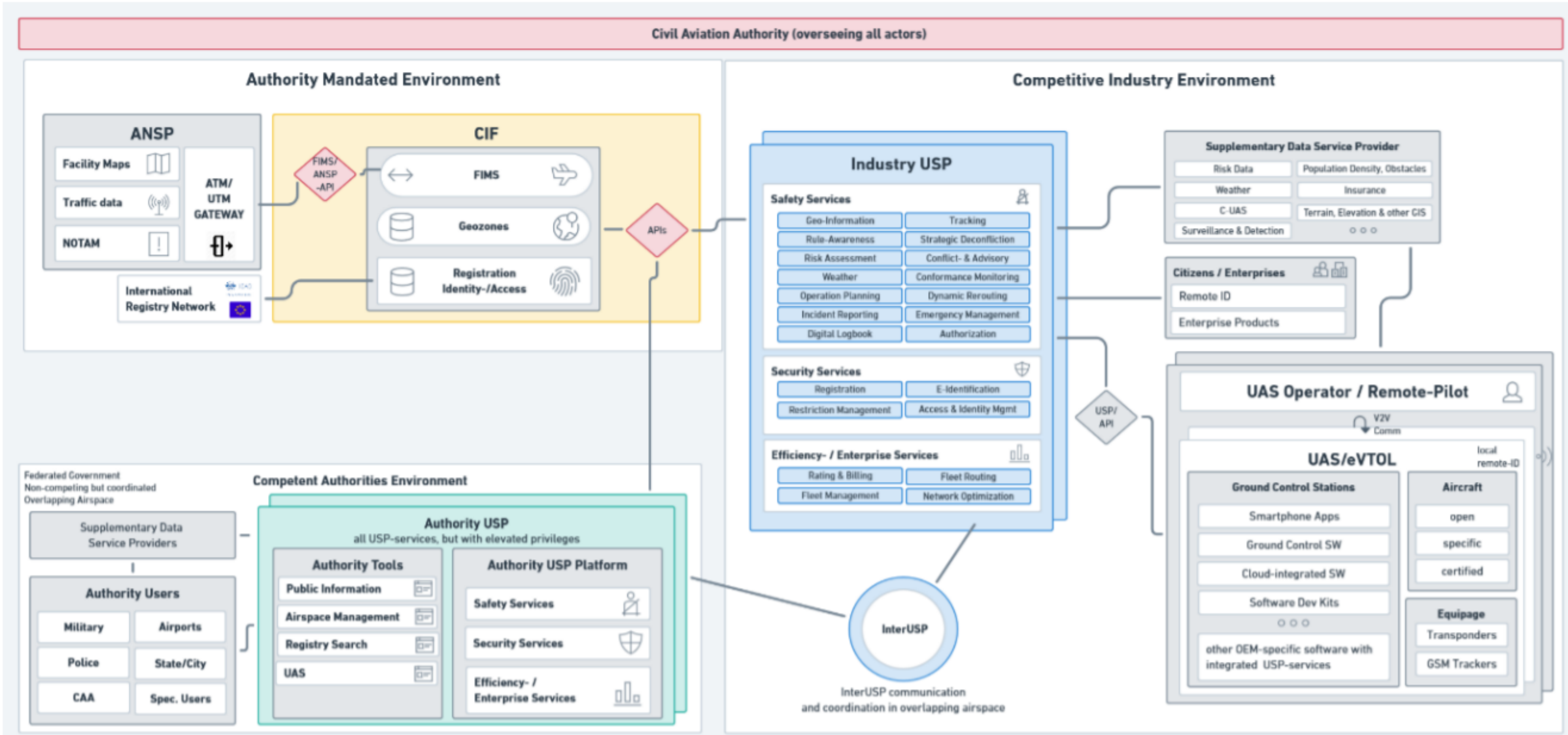


Figure 20: Swiss Architecture of U-Space Overview

Credits: Photo Courtesy of Federal Office of Civil Aviation and the Swiss U-Space Implementation [42]

The architecture is modelled in a way that ultimately gives the relevant and competent authorities the opportunity to delegate and control who and what does different tasks. However, some further explanation of the different parts is required;

- **Common Information Function (CIF)**, is the function that is comprehensive in its regrouping of all the centralized capabilities and services, and also contains services such as the Flight Information Management system (FIMS), the national drone and operator registries and the geo-zone archive (with the two latter services being provided by the Swiss Federal Office for Civil Aviation or FOCA in their modelled architecture, but this can be altered to other nations Civil Aviation Authorities if they use the model).
FIMS is described in [42] as " a gateway through which the national ANSP can provide relevant airspace information available to UAS Operators via USPs". Additionally, the geo-zone archive is explained as a function driven by Article 15 of (EU) 2019/947 [43] which facilitates the prohibiting or restricting action on a drone through creating geographical zones (geo-zones) that cannot be breached for privacy, security, environmental and safety reasons, moreover the establishment of these geographical zones are the general nations competent agencies (at different levels) responsibility.

- **USSP/USP** (USP term is chosen by the Swiss), is described in [42] as "an entity that provides services to support safe and efficient operations by providing services to the Operator and authorities". The USPs have several critical functions and characteristics, these enables cooperative management of operations and guarantees the sharing of critical situational awareness between different aviation actors through a network of USPs that does not involve the deciding and competent authorities.
The USPs function as a bridge between ANSPs, other USPs, UAS Operators, Supplemental Data Service Providers (SDSP), other stakeholders and public entities, for the purpose of information sharing in real-time or near real-time to manage different amounts and types of operations. Moreover, USPs aids the conflict deconfliction/avoidance and also the collaborative decision-making, that consequently encourages efficient operation, safety, and impartial airspace access. Furthermore, for regulatory, analytical and Operator accountability objectives, the USPs document operations data in chronicled databases. Another essential point is that USPs provide end users with fundamental services (e.g. registration and identification) and value-added services (e.g. risk-mitigation).

- **InterUSP Network**, is not exactly a function but a term made to describe the capability of USPs to cooperate and exchange information between themselves. In a region there will be several different USPs in effect at the same time, and a digital environment for the USPs will enable them to cooperate and maintain the constantly efficient information sharing, this is the "InterUSP Network". To elaborate, it specifies and organizes the interfaces and how the information stream flows between the USPs, but it does not hold onto or archive information. Additionally, there are global standards and rules that the network has to abide by, to the extent of handling significant amounts of USPs and UAS. Another essential point is the InterUSP Networks primary functions, they are to supply the information exchange capability, filtering out all non-relative and bad information being shared, and to establish and maintain the digital environment for the USP information exchange to the extent of being inter-operable with other segments of the U-Space system.

- **SDSP**, they provide additional information directly to Operators or other USPs and are in general not validated as other the general USPs but shall acct in accordance with the performance and technical standards that the system they are connecting to have. The role and responsibility for the Supplemental Data Provider (SDP) is expected to be specified and made clear by the system that makes use of it. Additionally, if an Operator makes use of an SDP without mixing in any aspects of the U-Space system, the SDP is not considered a part the U-Space.

- **Communication Service Provider**, it establishes the connection to the U-Space systems throughout operations, but the connectivity is not presumed to be acquired or sustained to any particular endpoint or by any particular procedure. Furthermore, the services are not constrained to/from just exchanging operational information with human entities, the cellular vehicle-to-everything is described as "being developed" in [42] to aid the future of autonomous operations for every kind of vehicle. Hence, [42] writes that dialogue between the UAS manufacturers and communication service providers is critical.

- **Authority USP environment**, is a digital environment created for competent authorities to use (e.g. military, police, airports) and it has its own tools and platforms adapted to the requirements of several authorities, and the USPs used in this specific environment is all the same USPs as in the general system but elevated privileges catered to the importance of the authorities.

- **Pilot Operator**, where an Operator is an entity or person accountable for the overseeing of the operation and has to adhere to the regulatory demands of an operator such as take on the responsibility, sharing information about operations intent openly, using all the relevant information that is available to maximize the safety of an operation, and taking care of the operation/flight plans. In addition, an Operator can be used as a USP (e.g. commanding a large fleet of entities) but will then have to follow the demands set for operating as a USP. Furthermore, a pilot is divided into two subcategories: automatic on-board system and a remote pilot. The automatic on-board system refers to certain levels of automation, low automation might be information collecting by on-board sensors and high automation might refer to automatic piloting and on-board decision making (with no to little intervention by humans).

- **UAS Manufacturer**, has its own purpose in this system as a department for making sure that equipment (drone or GCS) fulfils the necessary requirements before they even leave the factories. This was mentioned in the Delegated Act (EU) 2019/945 [44] where it was covered that several functions such as communication and geo-awareness were fundamental parts of secure and safe operations. Another significant point that is mentioned in [42] is that the capability for a drone to communicate instantly between other entities and drones will possibly have a consequential impact on the progress of U-Space services.

All of the previously mentioned actors work together to provide the end user with a multitude of services for efficiency and safety, these are explained in detail in [42]:

- Communication Service
- Discovery Service
- Authentication and Authorization Service
- Registration Service
- Remote Identification Service
- Airspace Authorization Service
- Geo-awareness Service
- Notification Service

- Rules Awareness Service
- Geographical Information Service
- Tracking Service
- Operation Planning Service
- Separation Services
- Risk Assessment Service
- Weather Service
- Noise Mitigation Service
- Liability Insurance Service
- Emergency Management Service
- Accident and Incident Reporting Service
- Digital Logbook Service

As an example on how the system would potentially work, we will later look at some use case examples set in a setting connected to oil-platform operations.

4 Regulations

The EU have written several regulations with regards to aviation, many of which is the ones that apply to any general aircraft. Since the continuous increase of drones, UAs and such, the EU have written specific additional regulations towards that field. The two main ones being [44] and [43]. However, there are written more and newer additions and amendments to keep the regulations up to date and the gaps filed in, such as [45] which amends [44], and [46] and [47] which amends [43], and several more. This next chapter and part names some of the most relevant rules from several regulations related to the U-Space systems Airspace, services and service providers, the UAV itself and its several categories and classes, the payload that can be handled, the operators and pilots' guidelines, what the manufacturers of UAVs and other equipment are to abide by, and everything previously mentioned.

4.1 Airspace

As presented in Figure 21 you can see the table presented in the appendix of [46], which shows the services related to U-space airspace and the different types of airspace classes that is related.

Class	Type of flight	Allowed in U-space airspace	Services in U-space airspace by USSPs
A	IFR only	Not without dynamic airspace reconfiguration	
	UAS (1)	Yes	UAS flight authorisation Traffic information about UAS
B, C and D	IFR and VFR	Not without dynamic airspace reconfiguration	
	UAS (1)	Yes	UAS flight authorisation Traffic information about UAS
E	IFR	Not without dynamic airspace reconfiguration	
	VFR	Yes, subject to sharing position with USSPs	Nil
	UAS (1)	Yes	UAS flight authorisation Traffic information about UAS and VFR
F	IFR	Yes, subject to sharing position with USSPs	Nil
	VFR	Yes, subject to sharing position with USSPs	Nil
	UAS (1)	Yes	UAS flight authorisation Traffic information about UAS, IFR and VFR
G	IFR	Yes, subject to sharing position with USSPs	Nil
	VFR	Yes, subject to sharing position with USSPs	Nil
	UAS (1)	Yes	UAS flight authorisation Traffic information about UAS, IFR and VFR

(1) Except UAS flying according to Instrument Flight Rules.

Figure 21: Table showing ATS airspace classes and U-space services provided
Credits: Photo Courtesy of EU [46]

4.1.1 U-space airspace

An airspace risk assessment shall support the designation of U-space airspace, when done so by a Member State for safety, security, privacy, or environmental reasons, as according to paragraph 1 of article 3 in [46]. In paragraph 2 of the same article, it is stated that network identification service, the geo-awareness service, the UAS flight authorisation service and the traffic information service referred to in article 8 to 11, are the mandatory U-space services that all UAS operations in the U-space airspace shall be subjected to. Additionally, paragraph 4 of article 3 say that for each U-space airspace, based on the airspace risk assessment and using the criteria set in Annex I of [46], Member States shall determine the UAS capabilities and performance requirements, the U-space services performance requirements and the applicable operational conditions and airspace constraints. As a part of the common information services of each U-space airspace according to paragraph 1 of article 5 in [46], Member States shall make the data available; horizontal and vertical limits of the U-space airspace, the requirements determined pursuant to article 3, a list of certified U-space service providers offering U-space services in the U-space airspace, any adjacent airspace(s), UAS geographical zones relevant to the U-space airspace, and static and dynamic airspace restrictions defined by the relevant authorities and permanently or temporarily limiting the volume of airspace within the U-space airspace where UAS operations can take place.

4.2 U-space services and service providers

To be a U-space service provider, you have to be qualified and certified, since you will be responsible for providing the UAS operators with the U-space services, according to Paragraph 1 and 2 of article 7 in [46]. Paragraph 3 of article 7 in [46] adds that U-space service providers shall establish arrangements with the air traffic services providers to ensure adequate coordination of activities, as well as the exchange of relevant operational data and information in accordance with Annex V ([46]). Paragraph 4 of article 7 in [46], states that U-space service providers shall handle air traffic data without discrimination, restriction, or interference, irrespective of their sender or receiver, content, application or service, or terminal equipment.
Paragraph 2 of article 8 in [46] states that the network identification service shall allow for the authorised users to receive messages with the UAS operator registration number, the unique serial number of the unmanned aircraft or the add-on (if privately built), the geographical position of the UAS, the altitude above sea level, height above surface, height above take-off point, the route course measured clockwise from true north, ground speed of the UAS, geographical position of the remote pilot, the emergency status of the UAS, and the time at which the messages was generated. Paragraph 4 of article 8 in [46] say that the authorised users shall be the general public, other U-space service providers, the air traffic service providers concerned, the single common information service provider (when designated), and the relevant competent authorities.
Paragraph 1 of article 9 in [46] say that a geo-awareness service consists of the following geo-awareness information shall be provided to UAS operators; information on the applicable operational conditions and airspace constraints within the U-space airspace, the U-space airspace relevant geographical zones, and the temporary restrictions applicable to airspace within the U-space airspace. Paragraph 1 of article 10 in [46] states that the U-space service providers shall provide UAS operators with the UAS flight authorisation for each individual flight, setting the terms and conditions of that flight, through a UAS flight authorisation service. Paragraph 11 of the same article states that U-space service providers shall issue a unique authorisation number for each UAS flight authorisation, which

enables the identification of the authorised flight, the UAS operator and the U-space service provider issuing the UAS flight authorisation.
Paragraph 1 of article 11 in [46] states that a traffic information service provided to the UAS operator shall contain information on any other conspicuous air traffic, that may be in proximity to the position or intended route of the UAS flight. Paragraph 1 of article 12 in [46] say that when providing a weather information service, U-space service providers shall collect weather data from trusted sources to maintain safety and support operational decisions for other U-space services and provide the UAS operator with weather forecasts and actual weather information either before or during the flight. Additionally, paragraph 2 of the same article mentions the minimum requirements for what the weather information service shall include, such as wind direction, wind speed, temperature, and dew points.

4.3 Drones/Unmanned Aircraft

4.3.1 Open category

UAS operations in the open category shall not subject to any prior operational authorisation, nor to an operational declaration by the UAS operator before the operation takes place according to article 3 in [43, 47]. Paragraph 1 of article 14 of [44, 45] says that all products that are compliant with the requirements set out in Parts 1 to 6, 16 and 17 in the annex, identifying a UAS' class, shall show its compliance through the EU declaration of conformity referred to in paragraph 8 of Article 6 in the same document.
The CE marking and UA class identification label on the product/UA are through paragraphs 1 to 5 of article 16 of [44, 45] required to be affixed visibly, legibly, and indelibly on the product/UA and packaging, before being released in the market. Specific mentions to the class label required to be at least 5 mm high, in addition to have the sound power level on the UA if it is warranted and possible.
Article 39 about formal non-compliance by products (UA) says in its second paragraph that the Member State concerned shall take all appropriate measures to restrict or prohibit the product being made available on the market or ensure that it is withdrawn or recalled from the market, based upon non-compliance of the several sub-point of paragraph 1 of the same article.
As stated in article 5, paragraph 1, products can shall only be made available on the market if they satisfy the requirements of chapter two of the regulations (and thus part 1 to 6 of the annex) and do not endanger the health and safety of persons, animals, or property. Products sold with implemented software may have the software updated, but only if the update does not affect the compliance of the product, according to article 4, paragraph 3 of [44, 45]. For a UAS operation to be classified in the open category, certain requirements have to be met. Such as MTOM below 25 kg, the UA is kept at a safe distance from people and that it is not flown over assemblies of people, the remote pilot keeps the UA in VLOS at all times, the UA cannot exceed 120 meters above the closest point of the surface of the earth (exceptions made over obstacles) and that during flight the UA does not carry any dangerous goods or drop any material. This is according to paragraph 1 of article 4 in [43, 47]. Additionally, paragraph 2 of article 4 divides UAS operations in the open category into further three sub-categories (A1, A2 and A3) in accordance with the requirements set out in Part A of the annex [43, 47].

4.3.2 Specific category

If the UAS operation falls out of one of the requirements in article 4 or Part A in the annex, the UAS operator shall be required to obtain an operational authorisation pursuant to article 12 from the competent authority in the Member State where it is registered, according to paragraph 1 of article 5 in [43, 47]. Paragraph 4 of article 5 states that the competent authority shall specify whether the operational authorisation concerns; point a in regard to a single operation or a number of operations specified in time or location(s) or both, point b in regard to the approval of a light UAS operator certificate (LUC) (in accordance with Part C of the annex). Which then again makes a UAS operator holding an LUC with appropriate privileges not having to acquire an operational authorisation or declaration, stated in point a of paragraph 6 of article 5 in [43, 47].
According to paragraph 5 of article 40, each UA intended to be operated in the specific category and at a height below 120 meters shall be equipped with a remote identification system that allows access to information registered in the registration system of the Member State (in accordance with article 14 of [43, 47]) and the periodic transmission of real time date such as UAS operator registration number and the verification code provided by the Member State, the unique serial number of the UA, time stamp, geographical position, height above surface [44, 45].
UAS operations in the specific category shall require an operational authorisation issued by the competent authority pursuant to article 12 or an authorisation received in accordance with article 16, stated by article 3 in [43, 47].

4.3.3 Certified category

UASs shall be certified if the UAS meets any of the conditions: characteristic dimension of 3 meters or more and is designed to be operated over assemblies of people, is designed to transport people, designed for the purpose of transporting dangerous goods, is used in the specific category of operations defined in Article 5 of [43], as per article 40, paragraph 1 of [44, 45].
To abide by article 3 of [43, 47], UAS operations in the certified category shall require the certification of the UAS pursuant to [44] and the certification of the operator and, where applicable, the licensing of the remote pilot.
Paragraph 2 of article 6 in [43, 47], adds that UAS operations shall be classified in the certified category where the competent authority, based on the risk assessment provided in article 11, considers that the risk of the operation cannot be adequately mitigated without the certification of the UAS and of the UAS operator and, where applicable, without the licensing of the remote pilot.

4.3.4 UAS Classes

UASs are separated into categories and also classes. Originally there were only four classes, one to four in the annex of the first regulation [44] in 2019. It was later amended and replaced by the annex of [45] in 2020, adding two classes, making it from class one to six. The classes differentiated by their requirements, such as maximum take-off mass (MTOM), maximum attainable height above take off point, general characteristics of allowed payloads, operational limitations, equipment, fuel.
For example, in [45] it is written that a UAS is in the C1 class if it has a MTOM of less than 900 grams (including payload), maximum altitude of 120 meters above take-off point, have a guaranteed A-weighted sound power level, be exclusively powered by electricity, have the ability to utilize

basic U-space features such as remote identification and geo-awareness. For a C4 class UAS, the requirements are such as the UAS have a MTOM of less than 25 kg (including payload), the UAS not being capable of automatic control modes except of flight stabilisation assistance and lost link assistance, no maximum altitude restriction (still has to get authorisation to enter certain airspace). All UAS is required to bear the label of their class in a visible manner, see label presented in Figure 22, in addition to manufacturers having to draw up instructions providing certain characteristics of the UA before being placed on the market. The characteristics include but are not limited to the class of the UA, the mass of the UA and MTOM, general characteristics of allowed payloads (mass, dimensions, interfaces, and other restrictions), equipment and software to control the UA remotely, description of the behaviour of the UA in case of loss of the command-and-control link, etc.

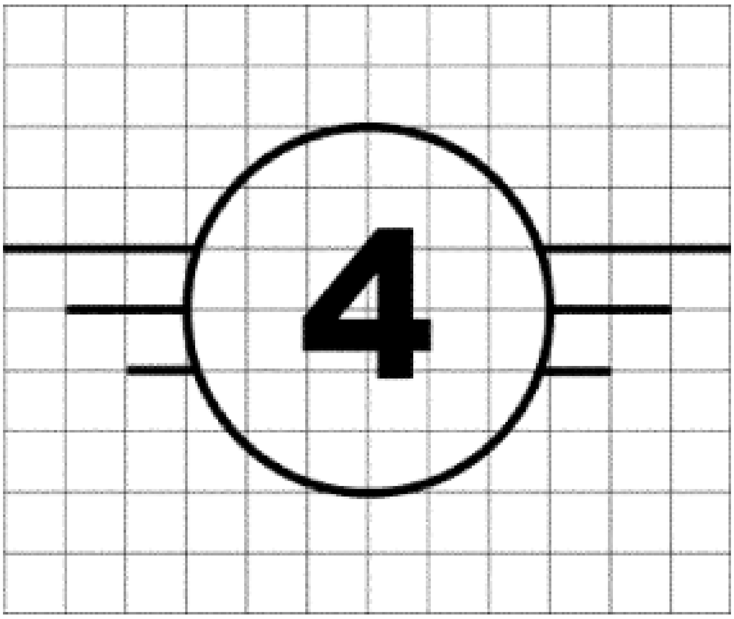


Figure 22: EU label for a UA meeting the requirements for class C4
Credits: Photo Courtesy of EU [45]

4.4 Payload

Any UAS that is designed to transport people, dangerous goods and requires a high level of robustness to mitigate the risks for third parties in case of accidents, will fall under the certified UA category, as per paragraph 1 of article 40 in [44, 45].
The payload a UA can have attached depends on the UA characteristics and class/category. According to the updated annex, Part 1 to 5 and 16 to 17 in [45], there are clear restrictions on what payloads are allowed from regulations restrictions and manufacturers restrictions, such as mass, dimensions, interfaces with the UA, what types of goods it is.

4.5 Operator(s) and Pilot(s)

Article 8 of [43, 47] describes the requirements for remote pilots operating UAS in the open and specific category, where the open category in paragraph 1 refers to the requirements set out in Part A of the annex. On the other hand, paragraph 2 list specific requirements for operating in the specific category, such as situational awareness, ability to manage aeronautical communication, problem solving and decision making. Article 9 of [43, 47] sets limitations when it comes to the age for remote pilots, with the first paragraph setting the age limit for remote piloting UAS in the open and specific categories to 16 years of age, while mentioning in paragraph 2 where there is no minimum age limit to operate certain UAS and UAS operations. Additionally, paragraph 3 and 4 states that a Member State may alter the age limit, what the max alterations are based upon the operational category and that if the age limit is altered, the new age limits is only valid in the specific Member State who altered it. Paragraph 1 of article 6 in [46] states that when operating in U-space airspace, UAS operators shall; ensure that the UAS to be operated comply with the capabilities and performance requirements determined in accordance with article 3 [46], ensure that the necessary U-space services are used and their requirement is complied with during their operations (referred to in article 3), comply with the applicable operational conditions and airspace constraints referred to in article 3. Paragraph 4 and 5 of article 6 in [46], mentions what the UAS operator shall do before each individual flight and when read to start the flight. These mainly elaborate further on which authorisations, airspace and other U-space related services, the operator has to submit to, and which has to be in place before starting an operation and/or flight. Paragraph 8 of article 6 in [46], states that UAS operators shall provide for contingency measures and procedures and make them available for U-space service providers.

4.6 Manufacturers

For any supplier that import whole products or parts, provisions should be made to ensure that the conformity assessment procedures can be carried out and that the CE marking and technical documents that are drawn up by the manufacturer, is accessible for inspection by the nation in regards competent authorities. Paragraph 1 of article 6 of [44, 45] states that when placing their product on the market, manufacturers shall ensure that it has been designed and manufactured in compliance with the requirements set out in Parts 1 to 6 in the annex.

Paragraph 2 of article 6 of [44, 45] states that the manufacturers shall draw up technical documentation and carry out the relevant conformity assessment procedure (or have it outsourced) referred to in article 17 and 13, respectively. Additionally, where compliance of the product with the requirements set out in Parts 1 to 6, 16 and 17 of the annex has been demonstrated by that conformity assessment procedure, manufacturers shall draw up an EU declaration of conformity and affix the CE marking.

Paragraph 5 of article 6 of [44, 45] says that manufacturers of UAS shall guarantee that the UA has a unique serial number for the purpose of identification to show complacency with the requirements defined in Parts 2 to 4 in the annex.

Article 13 is about conformity assessment procedures, in which paragraph 1 states that the manufacturer shall perform a conformity assessment of the product using one of the following procedures with a view to establishing its compliance with the requirements set out in Parts 1 to 6, 16 and 17 of the annex. The conformity assessment shall consider all intended and foreseeable operating conditions.

Article 17, paragraph 1 and 2, mentions that the technical documentation shall contain all relevant data and details of the means used by the manufacturer to ensure that the product complies with the requirements set out in Parts 1 to 6, 16 and 17 of the annex. In addition to being drawn up before the product is released on the market and being continuously updated [44, 45].

5 Examples of Use Cases

This chapter will present two use cases where we will look at UAV and UAV operations in certain scenarios. What limitations do these scenarios have in terms of the operating of UAVs and what the advantages and disadvantage the UAV itself have in the specific scenarios. Additionally, we will look and draw inspiration from one of the future minded companies use of UAV in experimentally and real scenarios. As well as what technologies are featured on the UAV and the ground station and what might be featured for best possible attributes from the equipment and system in general.

5.1 Use Case 1 - Missing person

For this first use case, the setting is a search and rescue situation. According to [48] the use of drones/UAVs in Search and Rescue (SAR) mitigates unnecessary human risks in addition to providing other SAR efforts with critical aid through various means. SAR missions conducted by drones are confirmed to make several processes much faster and safer, due to the autonomy, the agility and aerial access of the drones.
Assume we are out of the shore of Norway, where the weather is very rough and constantly changing, on a platform (example of the platform in Figure 23) where an arbitrary worker is working on his night shift. He or she is a mechanic that does maintenance on the various machinery on the platform, and for this particular machine, a part needs to be changed with a replacement. To acquire the replacement part the person needs to traverse the platform to the replacement parts storage facility. On the way across, the person utilizes a walkway on the outside of the platform since it is a more straight and efficient way. It has been raining for some time and the walkway, made up of metal grids, is slippery. Suddenly the person is put off balance by a strong gust of wind and lose their footing, as a reaction the person tries to grab hold of the railing available but misses and ends up in the ocean below. Meanwhile, a colleague tries to get hold of the person to check up on them, because he knew that the trip normally does not take this long. After a couple tries the colleague assumes that something must have happened and calls in ”man overboard”. The message spreads and the other workers tries to locate the missing person below with spotlights while the shift manager send the emergency signal to various SAR departments, including the drone department located on the platform. The drone operator sets up the drone and the systems, then sends the drone off to aid in the SAR situation. There are four different results to the drone Search and Rescue mission, the first one is the drone completes its mission by finding the missing person and alerting the nearby vehicles of the position it has. The second result is that other vehicles/persons find the missing person first and the drone aborts its mission and returns to the drone-pad. The third result is that any anomalies happen during the search like low battery, the weather conditions are too bad or other miscellaneous anomalies that forces the drone to abort mission and return as a consequence. Finally the last result is that the entire search is being called off by the person or department in charge.
In our scenario, on a platform offshore there have been expansions made to the platform to accommodate a drone Ground Control Station (GCS), storage/docking for the drone(s), charging/refuelling station and a drone landing platform or a drone-pad (like a helipad but smaller and for drones). We have chosen a VTOL drone as our drone mainly because it can vertically take off and land, and making take off from a platform with minimal space possible, but there are both advantages and disadvantages for other build types of drones as you can see in Figure 24.

Figure 23: Statfjord A platform
Credits: Photos Courtesy of Harald Pettersen/Equinor

	Advantage	Disadvantage
Fixed – wing	• Long range • Endurance	• Poor manoeuvrability compared to VTOL • Horizontal take-off, requiring substantial space
Tilt- Wing	• Combination of fixed-wing and VTOL advantages	• Technologically complex • Expensive
Unmanned Helicopter	• VTOL • Good manoeuvrability • High payloads possible	• Expensive • Comparably high maintenance requirements
Multicopter	• VTOL • Affordable cost • Easy to launch • Light weight	• Limited payloads • Vulnerable to wind due to low weight

Figure 24: Strengths and weaknesses of different drone build types
Credits: Photos Courtesy of [48]

To elaborate, the initial deployment of the system and drone(s) shall be efficient enough to only take a few minutes or less, since time is a key element in Search and Rescue. Especially in maritime Search and Rescue, where the missing person or person in distress is fighting a battle against the sea, which can drain a normal person for energy in minutes and thus end up dying. By "initial deployment of the system and drone", several processes are referred to. Such as taking the drone out of storage and preparing it with initial checks, making sure the link between the drone and GCS is good (to get camera feed, positioning, drone status etc.) and choosing between automatic pre-made flight-plans or manual control. Additionally, the GCS linking up with U-Space, which is available for everyone 24/7, to get additional information that might prove critical, like weather information, current information, situational awareness information, location of other SAR units.

5.1.1 Drone Specifications

As mentioned before, SAR situations are very time sensitive, hence all the choices of drone specifications are driven by the incentive of facilitating the most efficient operation by the drone for these scenarios.
The specifications are:

- **Camera**, one or several cameras possibly being of the thermal kind to distinguish a bodies heat and the cold the ocean, or Electro-Optical/Infrared (EO/IR) to provide more of a wide-area situational awareness through geographical images in any weather conditions.
- **Transmitter**, the drone shall be equipped with a transmitter that is capable of sending out signals in the toughest conditions at an optimal range, this is to facilitate the communication from the drone to GCS or other entities.
- **Receiver**, the drone shall be equipped with a receiver (either GPS or GLONASS, the latter is preferred in the northern regions of the world) to facilitate communication from GCS, other entities, or satellites.
- **ATmospheres EXplosives (ATEX) qualification**, the drone will follow the security requirements that is based on operating in ATEX zones (ATEX Directive 2014/34/EU) [49], which is the existence of a potentially explosive atmosphere caused by mixture of dust, vapours, air gases, or mists that have the possibility to ignite under certain operating conditions. Allowing the drone to operate in the near vicinity of the platforms is an important point as to abide by the rules, so that the capability is enabled.
- **Emergency flotation system**, in the case that an anomaly incident happens and the drone crashes, runs out of fuel or such events like that, the drone shall be equipped with a flotation mechanism so that the drone can be rescued or salvaged.
- **Lifesaving payload**, the drone has a payload of a safety-vest or an inflatable device that the person in distress can use to stay afloat until further rescue happens [48].
- **Lights**, the drone shall be equipped with minimum small LEDs that flickers to show the drones position to other vessels in the vicinity, also it can be an option to have spotlight on the drone to highlight visually where the person in distress is located to others in the vicinity.
- **Speakers**, another optional attachment is a speaker that lets the operator(s) communicate with other personnel in close range or with the distressed person directly.

5.1.2 GCS Specifications

With inspiration taken from Schiebels [50] GCS for their Camcopter S-100, the main specifications for the GCS are:

- **Data link**, the systems of the GCS have an encrypted data link that supplies an extraordinary line-of-sight range [50].
- **Dual-redundant Inertial Navigation System**, is a type of system that has the ability to calculate the exact position of the entity, relative or absolute, and is comprised of a minimum of three gyros and three accelerometers that facilitates to derive a navigation solution. The output of this system is at least the longitude and latitude (position), but today the system normally provides the Heading, pitch and roll also, additionally some system may offer the possibility to provide heave, sway, and surge as well [51].
- **GPS**, a positioning system that guarantees accuracy of the highest level for navigation and stability, that may also include the option to integrate anti-jamming features [50].
- **Payload Control**, is an independent workstation that covers the payload systems that facilitates the operation and control of the payload bays on the drone, all while having the opportunity to observe, record and frame capture the payload or around the payload (if the payload is attached underneath by hook or cargo-net) [50].
- **General Control Workstation**, is the main workstation for all the general system information, such as displaying the position of the entity, weather information, fuel status and other critical status information in real time [50].
- **Management system**, is the system that acts as a central node/meeting point between the drone (via the data link), all ground components and the higher-level networks (i.e. U-Space) [50].

5.2 Use Case 2 - Payload transportation

The second use case is more of a logistic case rather than a critical lifesaving one (can be a combination of the two), the possibility of using drones to transporting small to medium size payloads from a base on land to boats further out in the sea and even out to the platforms. For this scenario we have acquired a drone base where the GCS is stationed, all the drones will take off from this base and is stored there, preferably close to existing platform bays or shipping yards. Initially the operator(s) take the drones out of storage/docking and do the mandatory integrity checks on the drones. Then in the same way as the previous use case, the drones are turned on, operator(s) log on to the system (registering drones, operator(s) and logging time and date) and begins establishing a reliable link. Meanwhile, the payloads are made ready for pickup and transport by the other operators/personnel. When the link is up and everything checks out according to the pre-flight checks, the drone(s) can be sent out by pre-made automated flight plans or manually by the operators, but the drones have to be sent out with a delay between each of them for the purpose of not crowding the smaller drone-pad with several drones at the same time, and additionally to give the platforms drone personnel time to unload the payload from the current drone and move it aside/inside so that the drone-pad is ready for the next drone with the next payload. In this use case, depending on the battery technology level, will either drop off the payload without landing and head straight back to the land base, or the more likely scenario is that the drone will have to land at the platform to charge up its battery or exchange the battery to a fully charged one (depending on battery solution used on the drones and if it is a fact that the solution is a hundred percent electrical).

Figure 25: Illustration of the situation in use case 2

This scenario has already been tested in real operations by Equinor [52] in cooperation with the Civil Aviation Authority, Avinor Air Navigation Services, the Norwegian Communications Authority and Nordic Unmanned, who were the operator of the drone, back in 2020, it was widely covered by news channels in Norway and all over the world since it was the first logistics operation with a drone to an offshore installation. According to their website, Equinor flew a drone over a distance of 80 km with a flight level of approximately 5000 feet (or 1.5 kilometres), to their Troll A platform in the north sea and back again to the base in Mongstad (illustrated in Figure 25) outside Bergen, Norway, to drop off a 3D-printed part that was to replace an old part in a lifeboat system, which is critical and potentially time-sensitive. The operation was successfully completed efficiently and according to plan, which confirmed and gave reassurance of their theories and mentioned in a statement by Arne Sigve Nylund, Equinor's executive vice president for Development and Production Norway; "Drones could reinforce safety, boost production efficiency and contribute to lower CO2 emissions from Norwegian oil and gas". Equinor also has more plans for drone usage than just logistics operations, such as inspections and observations of the technical conditions of their offshore platforms and onshore facilities, in addition to playing a role in new energy solutions based on the Norwegian continental shelf.

5.2.1 Drone Specifications

Since the use case in focus has been tested, the requirements will be taken from the actual equipment used in the testing by Equinor.
The drone used in the test of the use case is a Camcopter S-100 model provided by Schiebel, and Equinor stated that the drone has been thoroughly tested and has logged about 70,000 flying hours from other types of operations for the defence and coast guard services. Schiebel writes on their website [50] that the drone is "a proven capability for military and civilian applications", it is of the type Vertical Take-off and Landing (VTOL) UAS resembling a helicopter aesthetically and thus does not require a runway or supported launch. The adaptable drone is sturdy, weatherproof against dangerous and versatile weather conditions, has the range of 200 kilometres (communication range) and is operable 24/7 on both land and at sea. It has a wide range of payload/endurance combinations thanks to the carbon fibre and titanium fuselage that supplies the capacity for it, hence it is not a pure electrical drone. In addition, the drone can be operated manually with the provided "pilot control unit" in the GCS, or it can navigate by itself automatically through waypoints in the Global Positioning Systems (GPS) that are pre-programmed.
In Figure 26 and 27 we can see the performance and technical specifications of the Camcopter S-100 by Schiebel:

Maximum airspeed (V_{NE})	130 kn (240 km/h) IAS
Dash speed	120 kn (222 km/h) IAS
Loiter speed	55 kn IAS (102 km/h) for maximum endurance
Endurance	>6 h with 34 kg (75 lbs) payload plus optional external fuel tank extending endurance to >10 h
Service ceiling	18000 ft in ISA conditions @ reduced GW
Airframe loading	+3.5 g to -1 g rated
Operating temperature	-40°C to +55°C (-40°F to +131°F)
Wind (takeoff and landing)	Up to 25 kn (46 km/h)

Figure 26: Performance Specifications of the Camcopter S-100

Main rotor diameter	3400 mm (133.9”)
Total length	3110 mm (122”)
Total height	1120 mm (44”)
MTO weight	200 kg (440 lbs)
Empty weight	110 kg (243 lbs)
Payload capacity	50 kg (110 lbs)
Fuel (internal tanks)	57 l (15.0 gal) AVGAS 100LL, JP-5 (NATO F-44), Jet A-1 (NATO F-35)
Payload electrical power	1000 W @ 24 V DC
Data link range	Up to 200 km (108 nm) available

Figure 27: Technical Specifications of the Camcopter S-100
Credits: Photos Courtesy of Schiebel [50]

Additionally, some of the other specifications chosen to be included (or are able to adapt to) for the drone, specifically by Schiebel and for their use cases (including this one), are listed below and can be seen in Figure 28 and 29:

- **Real time video**, facilitates the operators with the ability to observe obstacles, conflicting traffic, observe terrain after missing person with great definition [50].
- **Dual GPS**, it provides accurate navigation using signals from two different satellites with different frequencies, this nullifies any multi-path errors occurring [53].
- **GLONASS receivers**, is a L-band radio processor that has the ability to calculate the navigation equations to pinpoint the exact position of the unit, the velocity, and the precise time, by processing the signal distributed by the GLONASS satellites [54].
- **Adaptable Mainframe**, can adapt its body to facilitate several payload bays, in the nose, sides, auxiliary with a weight up to 10 kg, and the main payload bay underneath the drone with a weight up to 50 kg [50].
- **EO/IR camera**, supplies through identification, geo-location, categorization, and collection of moving and stationary objects of interest, intelligence gathering and advanced wide-area situational awareness. All given to the operators and decision makers by real-time, high-definition video to facilitate several different observational possibilities in both night and daytime. The camera has 4-axis fully active stabilization, as well as the highest performing camera enhancements for zooming, colour and picture correction, and thermal imaging [50, 55].

- **Lightweight Electronic Support Measures (ESM) systems**, facilitates situational awareness over large areas and intelligence gathering through identification, geo-location, categorization, and collection of complex emitters. Highly accurate and precise compared to other systems [55].

- **Synthetic Aperture Radar (SARa)**, it simulates an extremely large aperture or antenna electronically through the usage of the flight path of the platform, and it creates high resolution remote sensing imagery. Essentially, it recreates images of such things as landscapes, in 2-dimensions or 3-dimensions high-resolution representations. The system can supply precise surveillance imaging and mapping in all weather conditions, as well as Ground Moving Target Indication. The mapping system is highly reliable and has a map resolution of under 1 meter, in addition to having a range of up to 20 km depending on the resolution choice [50, 55].

- **Laser Imaging Detection and Ranging (LIDAR)**, is a remote sensing technology that analyses reflecting light after illuminating a target with laser to measure distances with the greatest precision, accuracy, and flexibility. It facilitates examination of both natural and human environments for 3-dimensional geographic survey systems and creates highly accurate digital elevation models and maps for use in geographic information systems.

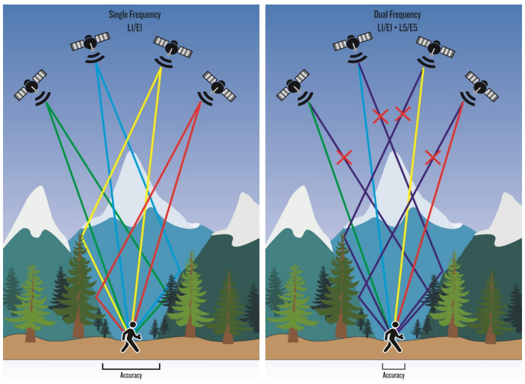
- **Signals Intelligence (SIGNIT)**, is a special type of intelligence collecting system that intercepts signals between people or systems, and consequently improves the efficiency of intelligence and monitoring missions [50].

- **Hyperspectral image sensors**, is the collecting and processing of information across the electromagnetic spectrum, and the sensors are the ultimate way of mapping vast geographical areas with high accuracy and efficiency. Consequently, the sensors have the ability to present mineral resource development on the surface of the earth [50].

- **Automatic Identification Systems (AIS)**, are transponders designed to supply the identification, position, and other information about the entity to other entities and to the relevant authorities automatically [56].

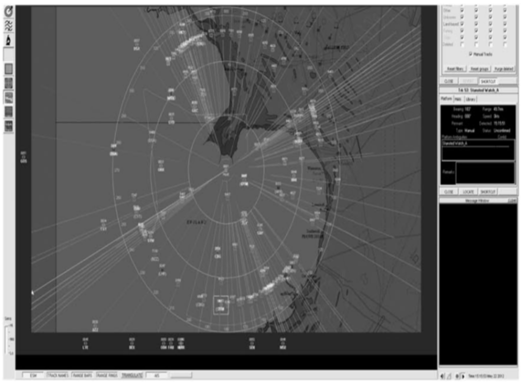
- **Spotlights**, are used to light up necessary and specific areas of desire. It can be used in several use cases such as inspection, search, and/or rescue.

- **Speakers**, projects sound out in the immediate vicinity to alert or give information. It can be used in several use cases such as inspection, search and/or rescue.



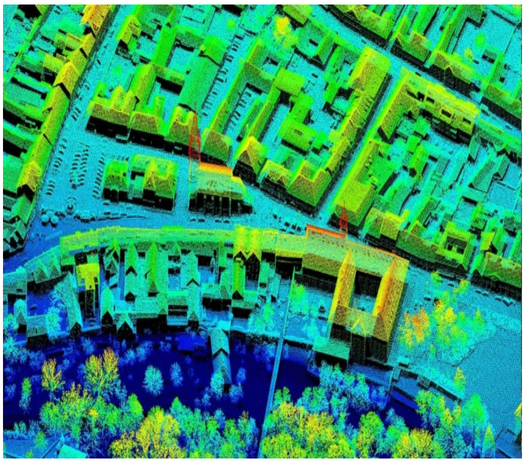
(a) Dual GPS

(b) EO/IR imagery

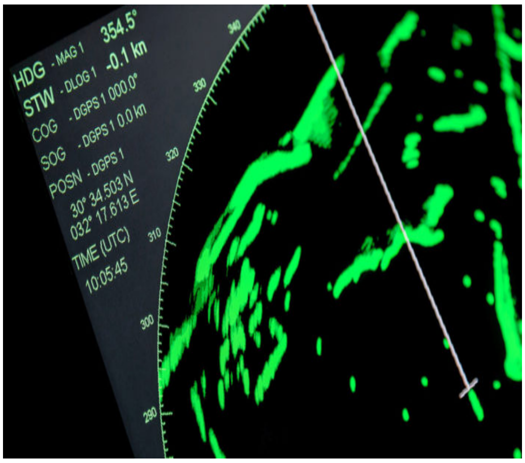


(c) EMS imagery

(d) SAR imagery



(e) LIDAR imagery



(f) Signit imagery

Figure 28: Sensory technologies

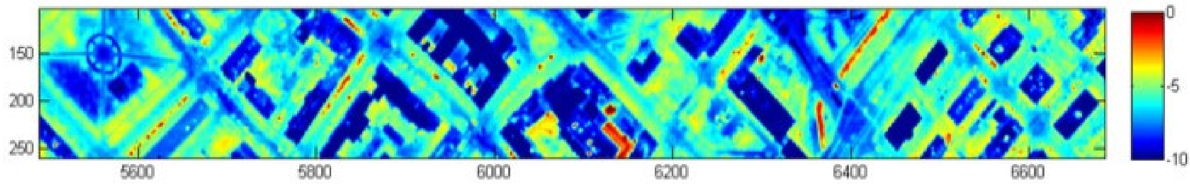


Figure 29: Hyperspectral imagery

5.2.2 GCS Specifications

From Equinors website [52] the ground control station is described and shown as a small shipping container that is equipped with the necessary antennas, computers and such, to communicate with other systems, receive and send out information, monitor and track the drone, keep tabs on the trajectories, status of the drone, fuel, altitude etc. Also, the GCS is able to receive high-definition payload imagery in real time, transmitted directly from the drone.
The use of point-and-click graphical user interface makes mission planning simple for the operators in the GCS, as well as the use of "fly-by-wire" technology controlled by redundant flight computers facilitates the operability of the UAVs in the most complex of electromagnetic environments.
Since the GCS is confined to a 20' container (exact measures are 6060 mm x 2440 mm), and can store the drone and additional equipment, it can easily be transported to other desired locations, but can also be adapted to be a mobile station surprised of two small trucks, thus if newly arrived at a location the quick setup time is reportedly 3 hours, and since it is stated on Schiebels website that the drone can be operated by just two persons, we assume that these two are the only ones setting up the system in those 3 hours as well. Additionally, several of the systems in the GCS are (visually presented in Figure 30):

- **Data link**, the systems of the GCS have an encrypted data link that supplies an extraordinary line-of-sight range in addition to extra antenna choices that extends the range up to 200 km [50].
- **Dual-redundant Inertial Navigation System**, is a type of system that has the ability to calculate the exact position of the entity, relative or absolute, and is comprised of a minimum of three gyros and three accelerometers that facilitates to derive a navigation solution. The output of this system is at least the longitude and latitude (position), but today the system normally provides the heading, pitch and roll also, additionally some system may offer the possibility to provide heave, sway, and surge as well [51].
- **GPS**, a positioning system that guarantees accuracy of the highest level for navigation and stability, that may also include the option to integrate anti-jamming features [50].
- **Payload Control**, is an independent workstation that covers the payload systems that facilitates the operation and control of the payload bays on the drone, all while having the opportunity to observe, record and frame capture the payload or around the payload (if the payload is attached underneath by hook or cargo-net) [50].

- **General Control Workstation**, is the main workstation for all the general system information, such as displaying the position of the entity, weather information, fuel status and other critical status information in real time [50].
- **"CUBE" hub**, is the system that acts as a central hub between the drone (via the data link), all ground components and the higher-level networks (i.e. U-Space) [50].

(a) The different components that comprises the GCS. (b) The GCS that can also be used as storage.

Figure 30: UAV and ground station

Credits: Photos Courtesy of Schiebel [50]

5.3 Link to previous Chapters

The scenarios presented and UAV usage in general would benefit from utilizing the U-Space system. The system provides the ability to organize and structure the connected vicinity of operations and the entire airspace by enabling communication (can be actual communication or just positional information and status of the UAV and counterpart) between smaller units like UAVs (in various sizes) and other units, be it other UAVs or bigger vessels (regardless of the medium of the vehicle). It would also benefit operations through additional service providers that provide supplemental information to be used in preparation or just overall better situational awareness, as presented in Chapter 2 and 3 [31, 35, 36].
In addition, the regulations put forward by the EU commission gives guidelines for the U-space systems, as well as determining requirements and proper conducts for UAVs, operators, and pilots from the regulations [43, 44].

6 Discussion

The newfound possibilities of utilization of UAVs, have resulted in reports of projected and actual increase in drone usage for various and several operations or missions. Due to the increase of UAV usage and the accessibly of UAVs, every nations' relevant authority and the EU have seen the need establish separate regulations specifically for UAVs and UAV operations. These regulations are relatively new, so as the loopholes are found, they are going to get filled and update the regulations accordingly. Additionally, similar to the trade deal within the EU, the EEA, the idea of a Single European Sky with as similar regulations as possible for every nation seems like good idea for the community of UAV users. Although, that really depends on if the plans they have laid out can be put into life and actually work in practise. Which so far, it seems to work according to plan. The thing that might not be as according to plan as thought, is that some countries that are not as strong economically and whose government might use longer time to implement the steps of the proposed plan, they will potentially not be as up to date as for an example here in Norway.
The timeline that is proposed in the EASA roadmap seems a little optimistic, in regard of every member nation. Now during this project, I have not been able to find any documentation that confirms how far along the timeline or the plans in regular, every nation have proceeded. It seems very likely that since there is so many nations, there is going to be a possibility to that some nations might not be able to keep up with the timeline, or alternatively rush the implementation just to show that they kept up with the timeline.

The development of UAV equipment and operations, both logistically, technologically and in quantity, is positive. It confirms the need to establish and develop a functional system with fair and accommodating regulations and will allow UAV operations to be progressed in an efficient manner to the extent that they ultimately are perceived as efficient and the way of the future. As every aspect around UAV gets more advanced and matured, the possibilities for the operations and technology will open up and increase, as well as the markets acceptance of the use of UAVs and their operations. Additionally, the faster UAVs get to prove themselves in actual projects, the more other actors in the market will see the potential of UAV usage in various scenarios.
Currently, the technology is not as affordable and available as it needs to be to cater to the mass market, but that will hopefully change as it becomes more and more of a mainstream product and operation method. Such things as more affordable ways to produce things like UAVs has been seen to come for other products such as laptops for an example, with technological advancements and the passage of time.

In regards of the regulations, some areas are left up to the nation it regards to choose from their experience or preferences. In my opinion that might tamper or shift the simplicity of transitioning between borders. That might just be between some borders, depending on what each of the nations decides to implement, but it will still impact the whole system. The system seems like a guideline for nations to follow to a certain extent, but if the parts that they can choose for themselves becomes too dissimilar from the rest, that specific nation might become side-lined by the community of the Single European Sky. Some UAV operators might refrain from traveling specifically to a certain nation, only justified by the operators opinion being that the nations regulation may be difficult to adjust to since it is so different from the rest. In my experience, people tend to refrain from something if it is too dissimilar resulting in it being perceived as too difficult to figure out or understand.
Since there are several different regulations that are in effect, with them continuously being amended and adding more, it would be increasingly difficult for the "normal" operator to keep up with every

regulation. Hence, why the fact that EASA have made a complete document of the regulations with some explanation is a great addition to their website. It makes it much easier to follow up and abide by the regulations in place, and at the same time simplifies and explains some of the regulations for the more "civilian" UAV operator.

The roadmap laid out by the European commission seems doable and catered towards every member nation being able to complete them over a certain time frame, regardless of how the status of the nation is. Additionally, given the increase in UAV usage, it makes sense to "unify" the member nations around this specific topic, and the way it is being done makes the plans seem more viable to accomplish. In addition, the U-Space system will make UAV operations more organized for the operator since it will provide information on other factors such as weather, other technologies that might affect the operation through signals and such, positional and other various information about other vehicles and units and vice versa.

All in all, the thesis gives a good overview of the current situation, current frameworks, current plans, current timelines, and current regulations in regard to the U-Space System. It goes over the main points that are relevance as well as diving deeper into specific points that are fundamental, but there is still more information from the various plans and regulations that are more side-tracked to fill gaps and holes. Additionally, it has been shown that the UTM framework and U-Space plans have both pros and cons. However, mostly advantages for organizing occupation of airspace, getting additional information that can be used in operations to be better prepared, ensuring safety in the air and better communication between occupant in the airspace.

7 Conclusion

This project has been performed as a preliminary study into Unmanned Traffic Management and U-Space. As a way to get an overview of the UAV system Single European Sky that is to be implemented in every member nation of the EU and the EEA trade deal as decided and proposed by EASA and the EU commission. This takes into consideration an overview for the general aspects, the technical aspects, and the regulatory aspects, for the system and its factors. As mentioned in the Objectives of this project as a part of the subtasks:

- In the beginning of the thesis we performed a literature review of different papers that is about the different systems that could be used in the U-Space plans and the different technologies presented. As well as how some of these systems and technologies have been used practise in experimental scenarios.
- We have performed a review of the roadmap laid out by EASA on how to integrate the proposed Single European sky plans through implementation steps. In addition to reviewing the different factors of the roadmap plans.
- We have looked at the structures and architectures of some different types of UTM and U-Space and seen what each of them does that differentiates them. As well as deciding which one would be the most beneficial to use for our case on the Norwegian continental shelf.
- We have taken a look into how the EASA roadmap plans to integrate their system without disturbing the existing manned air activity.

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Appendix

Roadmap Capability/ Service Name	Capability Model / Capability Level 3 Name
e-Registration	Registration
e-Identification	Surveillance Services Provision
Tracking	Surveillance Services Provision
Pre-tactical geofencing	Drone Aeronautical Information Provision
Tactical geofencing	Drone Aeronautical Information Provision
Dynamic geofencing	Drone Aeronautical Information Provision
Drone aeronautical information management	Drone Aeronautical Information Provision
Emergency management	Emergency Management
emergency recovery	Emergency Management
Monitoring	Surveillance Services Provision
Traffic information	Situational Awareness
Strategic deconfliction	Drone Operational Planning Management
Tactical deconfliction	Conflict Detection and Resolution (tactical)
Detect & avoid	Remain Well Clear
	Collision Avoidance
Weather information	Meteorological Observation and Forecasting
Flight planning management	Drone Operational Planning Management
Operations management	Drone Operational Planning Management
Dynamic capacity management	Dynamic Capacity Management
Procedural interface with ATC	Drone Procedure Design
Collaborative interface with ATC	Interface with ATS
Security	Security Monitoring
Communication, navigation and surveillance	Surveillance Services Provision
	Navigation Services Provision
	Communication Services Provision
-	Recording and Analysis
-	Ground Risk Observation

Figure 31: Roadmap elements mapped to capabilities
Credits: Photo Courtesy of CORUS [35]

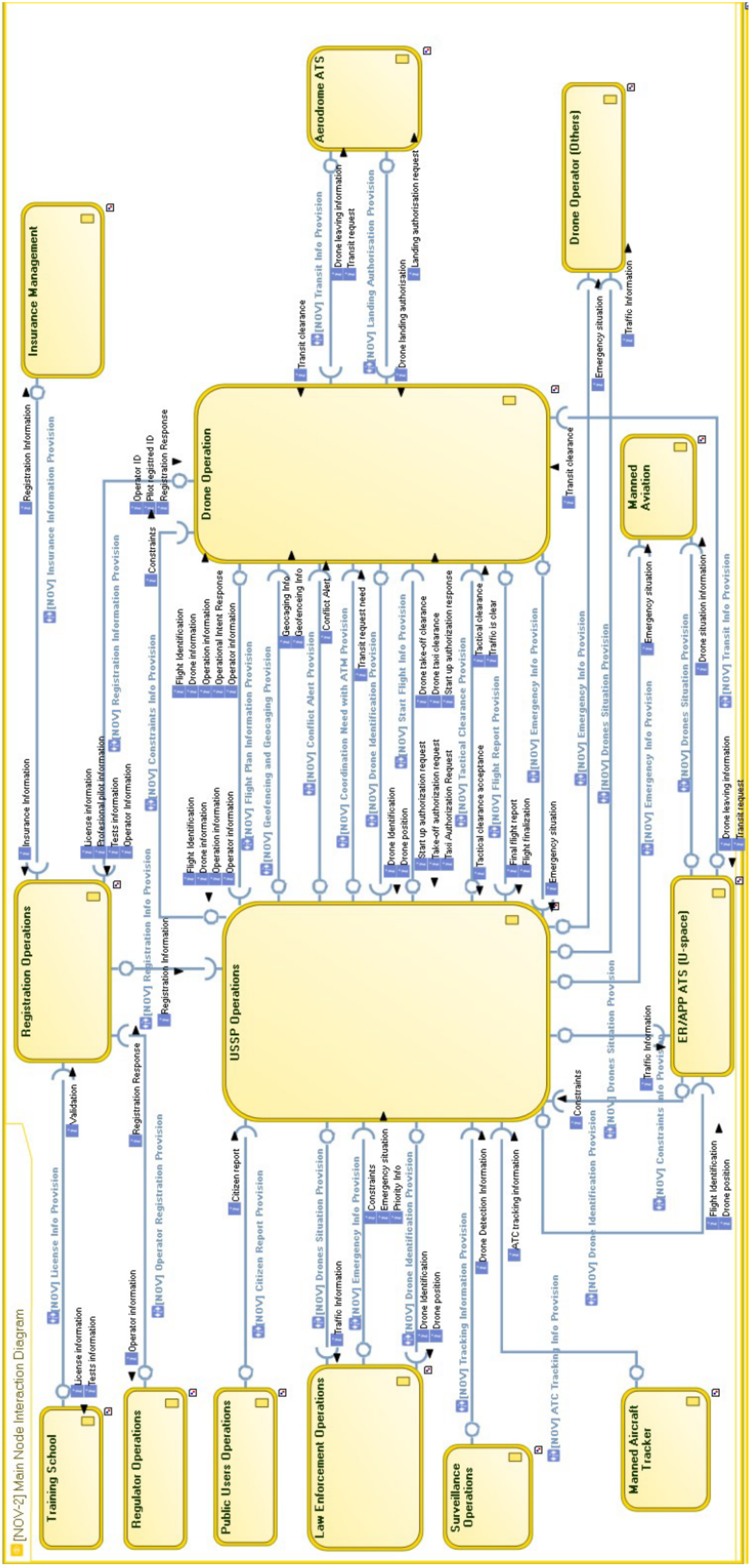

Figure 32: Main Node Interaction Diagram
Credits: Photo Courtesy of CORUS [35]

Node	Description
USP Operations	Performs all the operational activities related to management of drone traffic. This includes the activities required at strategic level, in execution and post flight to ensure a safe execution of drone flights. It is as well encompassing activities to maintain/monitor physical condition of the supporting infrastructures, creating and maintaining a good relationship with local / national authorities, ATM and communities. It also includes assurance that the scale of equipment and facilities provided are adequate for the activities which are expected to take place, as well as provision of staff, where necessary, that are competent and, suitably qualified.
Drone operation	Represents all the activities undertaken by those organisations and individuals who have access to and operate in the airspace which is available for drone operations in accordance with international and national procedures. For the purpose of this document only those actors directly involved in Drone operations are described. The main types of Drone Operations are: · Civil Drone Operations /Organisation. The most extensive organization for Drone Operations is run by Legal Entities which uses drones for their business activities. The daily operations of these companies require a lot of flexibility. · Recreational Drone Operations. Another important segment of Drone Operations which are constituted by single individuals which are aimed to use drones for recreational purposes. · Special Drone Operations /Organisation. Organizations for Drone Operations which require special conditions to operate, such as military/law enforcement. The daily operations of these companies require special condition of privacy in respect to the other organisations.
Registration Operations	Performs all the operational activities related to the registration of drone ownership, drone pilot and drone operators licensing according to the law. It is as well encompassing activities to maintain registrations, to share them with interested parties, as well as provision of staff, where necessary, that are competent and, suitably qualified.
Law Enforcement Operations	Performs all the operational activities related to the law enforcement. Most of the activities relies on U-space services to provide required law enforcement actions (e.g. e-identification).
Public Users Operations	Performs all the operational activities related to public when wants to be informed about drone traffic. These activities are mainly derived from privacy and safety issues of an individual/community.
Insurance Management	Performs all the operational activities related to insurance management. Even if the process can be considered outside the scope, for registration purposes it is important to mention these activities especially for the required exchanges in the e-registration process.

Meteorological Service Provision	Performs all the operational activities related to the weather information provision. Provides at least the weather data and where necessary hyper local weather data to ensure safe drone operations. In most instances a weather provider will provide a wider scope of weather data relevant to the ATM stakeholders/ATM community.
Terrain and Obstacles Provider Operations	Performs all the operational activities related to the provision of Terrain and Obstacles information.
Surveillance Operations	Performs all the operational activities related to the provision of Surveillance information
Navigation Operations	Performs all the operational activities related to the provision of Navigation information
Communication Operations	Performs all the operational activities related to the provision of Communication information
ER/APP ATS (U-space)	Performs all the en-route and approach ATS operations.
Aerodrome ATS (U-space)	Performs all the aerodrome ATS operations.
Flight Deck	Performs all the on-board AU operations including flight execution/monitoring according to agreed trajectory, compliance with ATC clearances/instructions, etc.
Manned Aircraft Tracker	Performs all the required activities to provide manned aircraft tracking information.
AIM	Performs all the operational activities related to the provision of Aeronautical Information
Training School	Performs all the operational activities related to the training schools. Provides information required for the registration process.
Regulator Operations	Performs all the operational activities related to the regulator.

Figure 33: Nodes with descriptions
Credits: Photo Courtesy of CORUS [35]

	Surveillance Services Provision	Navigation Services Provision	Communication Services Provision	Drone Operational Planning	Drone Procedures Design	Dynamic Capacity Management	Conflict Detection and Resolution	Remain Well Clear	Ground Collision Avoidance	Ground Proximity Terrain Avoidance	Geofence Infringement	Mid-air Collision Avoidance	Registration	Emergency Management	Interface with ATS	Security Monitoring*	Meteorological Observation and	Drone Aeronautical Information	Situational Awareness	Recording and analysis
Registration													X							X
e-Identification	X																			X
Tracking	X																			
Geofencing provision					X						X							X		X
Geo-Awareness					X						X							X		X
Emergency management														X						X
Strategic Conflict Management				X		X														X
Tactical Conflict Management							X													X
Interface with ATC															X					
Weather information																	X			X
Drone operational plan processing				X																X
Monitoring	X							X	X	X	X	X								X
Traffic information																			X	X
Drone aeronautical information publication																		X		X
Dynamic capacity management						X														X
Legal Recording																				X
Accident / Incident reporting																				X
Citizen reporting																				X
Registration Assistance													X							X
Drone operational plan preparation assistance				X																X
Risk analysis assistance																				X
Digital Logbook																				X
Geospatial Information									X											X
Population density Information																				X
Electromagnetic Information																				X
Navigation Coverage Information		X																		X
Navigation Infrastructure Monitoring		X																		X
Communication Coverage Information			X																	X
Communication Infrastructure Monitoring			X																	X
Surveillance Data	X																			X

Figure 34: Mapping of services to capabilities
Credits: Photo Courtesy of CORUS [35]

Stakeholder	Why it matters to stakeholder / what they expect
Drone operator	It is the legal entity, which can be a natural person, accountable for all the drone operations it performs. It is the equivalent of the airline for the pilot in manned aviation. It could be civil, military, an authority (special) or a flight club. It obtains fair, flexible & open access to the airspace. It is accountable for safe and secure operations. It expects that U-space further develops drone operations safe and socially acceptable which enables the development of new business models, spur jobs & market growth. It expects that U-space services protects privacy and confidentiality of competitive information (e.g. customer identity).
Drone Owner	It is the legal entity, which can be a natural person, owning the drone. It may be different from the Drone Operator legal entity (e.g. leasing rental mechanisms).
Drone manufacturer[6]	It produces drones and ensures their compatibility with U-space (technical feasibility, interoperability).
U-space Service Provider (USSP)	Generic stakeholder who provides one of the U-space services. The entity that provides U-space service access to drone operators, to pilots and/or to drones, to other operators visiting non-controlled very-low-level airspace. Depending on the architecture deployment options:

	• multiple services could be provided by different U-space Service Providers. • It is possible to distinguish between the providers of centralised services (i.e. **Principal USSP**) and concurrent service providers (**Operator USSP**)
Supplemental Data Service Provider (SDSP)	An entity that provides access to supplemental data to support U-space Services. Multiple services could be provided by different Supplemental Data Service Providers.
Weather Data Service Provider	It provides weather information data (hyper local weather data, solar flare information and TAFs and METARs) and ensures that these are reliable, accurate, correct, up-to-date and available.
Ground Risk Observation Service Provider	It provides supplemental data which contribute to the knowledge/observation of the ground. It encompasses: • ground and terrain data modelling (building heights, digital elevation model) and ensures that these are reliable, accurate, correct, up-to-date and available. • population density
CNS Infrastructure Service Provider	CNS infrastructures are constituting important U-space supporting systems. CNS Infrastructure SPs in general provide the availability of the CNS service and, where applicable, relevant monitoring and coverage services.
Communication Service Provider	It is responsible for the provision of a reliable and safe communication link between systems. It may contract different SLA to several Communication Service Providers, depending on the drone operations requirement and provide services to check coverage and monitor the status. For C2 Link it is aka C2-Link Service provider. It may be further classified as Terrestrial Network Service Provider or Satellite Service Provider.
Navigation Service Provider	It is responsible for the provision of a reliable navigation infrastructure to allow safe drone operations. It may contract different SLA to several Navigation Service Providers, depending on the drone operations requirement and access to airspace and provide services to check coverage and monitor the status. E.g. Satellite Nav Service providers.
Surveillance Service Provider	It is responsible for the provision of surveillance services with different technologies/methodologies and SLA. It encompasses anti-drone surveillance for non cooperative traffic. It provides services to check coverage and monitor the status of the surveillance service offered. Drone neutralisation is out of scope of the architecture,
Air Navigation Service Provider (ANSP)	Provides services to Airspace Users that may be operating in airspace where U-space services are also being provided
Aeronautical Information Management Provider (AIMP)	Existing ATM provides sources of some data consumed by U-space service providers and users. It is typically the ANSP.
(Airfield/Airport) Aerodrome operator (civil, Military)	Support the definition of operating procedures and interoperability requirements It expects that U-space ensures safe and secure integration of drones in airspace, especially in airport vicinity.

Civil Aviation Authority	Generic term to encompass national or local aviation authority. It expects that U-space ensures aviation law is followed, ensures safe and secure operation of all aircraft, promotes the minimisation of environmental impact and anticipates deployment challenges
Authority for safety and security (police, fire brigade, search and rescue orgs)	Publish danger areas in real time – relating to medical evacuation, police helicopter or similar (Police only) Develop law enforcement methods related to illegal drone use.
Local authorities (government/city / prefecture)	It supports the definition of operating procedures and rules. It explores applications of U-space to urban needs – for example active measures limit noise "dose" in any one place It expects U-space develops methods to support among the others: - privacy assurance - enforcement of drone regulations - publishing VLL hazards as they arise – cranes, building work, ... - derive added value from data generated by routine drone operations
Insurance companies	Collect statistics about drone accident rates in U-space. Propose more affordable insurance for drones that use enabling factors that lowers the risk of incident. Offer per operation insurance based on the specific operational plan. Providers supplemental data related to the insurance related to the U-space services. In that case it is an Insurance Data Service Provider.
Training Organisation	Remote pilot schools & Training centres Responsible for Pilot and operators training.
Aviation User	Users of the airspace other than drone operators / pilots. Includes those concerned with manned aircraft, parachuting and similar
The general public	Those who may hear, see or otherwise be concerned by a drone

Figure 35: Operational stakeholders
Credits: Photo Courtesy of CORUS [35]

Stakeholder	Why it matters to stakeholder / what they expect
Operation Customer	It is the final stakeholder of the drone operation who may have some roles in the authorisation of the mission itself.
Mission Service Provider	It is the legal entity, which can be a natural person, plans the mission executed by a drone, such as aerial photography, package delivery and climate survey. It is enabled by communication means, namely the mission link; it typically differs from the command and control link. The mission service provider does not conduct the flight of the drone, which is under the responsibility of the drone operator. The mission service provider and the drone operator sign a contract with the drone mission and flight plans to coordinate the joint execution of mission and flight. The interaction are expected to use/access to payload during the mission which is out of scope for this conops.
U-space Service industry	It develops sw products to realise U-space services. It expects that standards are issued for ensuring U-space interoperability. It provides a range of services implementation from basic to advanced solutions.
Equiment Manufacturer	It develops hw solutions needed or effected by U-space services. It expects that standards are issued for ensuring

	interoperability (if required). Equipments are for drone, manned aircraft and U-space infrastructure).
Manned Aircraft Manufacturer	It produces manned aircraft which can operate in an U-space environment and ensures their compatibility with U-space, integrating equipment needed for operation..
National Supervisory Authority	It will ensure aviation law is followed, ensure safe and secure operation of all aircraft, promote the minimisation of environmental impact and anticipate deployment challenges.
EASA/JARUS	Contribute to - implement an operation-centric, proportionate, risk- and performance-based regulatory framework for all UAS operations conducted in the 'open' and 'specific' categories; - ensure a high and uniform level of safety for UAS; - foster the development of the UAS market; and - addressing citizens' concerns regarding security, privacy, data protection, and environmental protection see https://www.easa.europa.eu/the-agency/the-agency for EASA see http://jarus-rpas.org/who-we-are for JARUS
European institutions (European Commission, SJU, Directorate General for Mobility & Transport (DG MOVE), Directorate General for Internal Market, Industry, Entrepreneurship & SMEs (DG GROW), EUROCONTROL, European Defence Agency (EDA)	Promotion of economic activity related to drone use They expect that U-space ensures protection of privacy, EU consumer rules conformance and safety with regards to protected sites (geofencing) *Further, EDA highlight:* To maintain the level of Safety for Military (low-level) operations , to preserve operational effectiveness and to protect Search and Rescue operations. To guarantee the Security of (Military) infrastructures, assets and operations. To quantify the financial impacts of U-Space implementation on the Military and to secure the necessary funding to maintain safety, guarantee security and ensure interoperability.
Universities and academic institutions and research projects (e.g. CLASS, CORUS, SECOPS) **+ Industrial research projects + test range**	Feedback, outcomes, results on current research issues, recommendations for additional industrial / research needs
Drone association (manufacturers & operators)	It represents Drone Pilots/Operators/Manufacturers and provide them assistance. They expect that U-space services realise an important enabling factor for the safe growth of the drone marker.
Flight Model Club	It represents modellers which needs to be distinguished from drone operators in the U-space access considering peculiarity of their activities.
Specialized press	It is responsible for communicating and disseminating information/news about this drone market.

Figure 36: Other stakeholders
Credits: Photo Courtesy of CORUS [35]

Role	Stakeholder	Explanation
Drone pilot	Drone Operator	aka UAS Pilot, Pilot in Command (PIC) or Remote Pilot, It is responsible for the safe execution of the flight according to the U-space rules, whatever it is recreational or professional with one of the different license levels, according to the typology of the drone used. (Recreational Drone Pilot, Professional Drone Pilot) It expects: • more efficient flight preparation, including getting permission (easier, quicker and more efficient); • safer and more efficient flight execution due to improved situational awareness in all operations – VLOS and BVLOS The person being registered in the pilot registry. A pilot is a human being performing the piloting function. The registry should be able to record some information about the pilot's qualification; mentions different levels of qualification. The drone pilot should be able to update some parts of his/her registry entry, such as changing his/her address and he/she may be allowed to create the record initially. How he/she interacts: User of geo-fence definitions during flight; User of situation awareness computed from the dynamic online traffic situation based on relevant maintained tracks; User of weather nowcast to assist him in the in-flight phase; the person receiving warning and alerts from the monitoring service.
Drone crew	Drone Operator Mission Service Provider	The drone pilot or any person following the drone's progress during flight. This term generalises the pilot, any kind of dispatcher, any mission specialist. Additional recipient of messages about flights. Drone Pilot Assistant. It is assisting the piloting in its duty. Observer. It is assisting the piloting in its duty, e.g. during EVLOS operations.
Drone operator representative	Drone Operator	Aka UAS Operator, the operator being registered in operator registry. An operator representative is a legal entity; meaning a natural person or a business. An operator representative has contact details. How he/she interacts: User of geo-fence definitions during flight planning, User of situation awareness computed from the dynamic online traffic situation based on relevant maintained tracks, Generalised actor that submits a flight plan, the person receiving warning and alerts from the monitoring service

Drone owner representative	Drone Owner	When any drone is registered, it will have a registered owner. An owner is a legal entity; meaning a natural or a business. An owner representative has contact details. How he/she interacts: User of drone registration.
ATS Operator	ANSP	ATS should have access to the air-situation generated from e-identification reports, with the usual controller-working-position tools to filter out those of no interest, give conflict alerts and so on. Main roles: Air Traffic Controller, Tower Supervisor, Tower Runway controller, Tower Ground controller, (A)FIS and RIS Operator. How he/she interacts: User involved to achieve the interface with ATS.
Police or security agent	Authority for safety and security	Security actors would be interested in the air situation, to identify operators and to apply relevant procedures. Law enforcement Unit, responsible to develop law enforcement methods related to illegal drone use. How he/she interacts: User of registration, e-identification and interested in the situational awareness and monitoring alerts.
Pilot	Aviation User	It is the pilot of glider, parachutist, paraglider, balloon, GA, military flight which share the airspace (even if occasionally) in VLL operations. How he/she interacts: In some environments, user of situational awareness and monitoring alerts.
Citizen	The general public	Generic person who wants to be aware of drone operations impacting its privacy. How he/she interacts: a kind of authorised viewer of air situation and able to report about events.
Registrar	Civil Aviation Authority USSP	A registrar has a legal duty to operate a registry securely, reliably and adequately. The registrar will be a legal person, probably with staff. How he/she interacts: who may intervene in case of problems in the registration
Accredited registry updater	USSP Civil Aviation Authority Insurance company Training Organisation	This category groups together pilot training schools, LUC issuers, nominated agents of the courts and any others who have the power to create, read, update or delete registry entries in any way – which may be very restricted for some. How he/she interacts: User of (operator/school/pilot) registrations.
Accredited registry reader	Authority for safety and security Civil Aviation Authority	This category groups the police, accident investigators, other agents of the authorities or anyone else who might need – and be given permission - to look into the registry. (or registries). How he/she interacts: Who may query registration information.

	...	
Drone Aeronautical Information Manager	ANSP AIMP	A body that is independent of the Aeronautical Information Office and allows drone specific aeronautical information to be registered, combines the information, assesses it and then published the result.
Drone specific aeronautical information originator	Authority	The person or representative of the organisation that creates drone specific aeronautical information. This actor is accredited and trained in the processes of creating, updating or deleting drone specific aeronautical information. This is reflecting the possibility to have a different originator of "constraints" for drones.
Authorised viewer of air situation	The general public Aviation Usuer Civil aviation Authoriy Drone Operator ...	This groups actors like U-space operators, city authorities and some others such as researchers who can be trusted with the commercially sensitivities of the overall air-situation. How he/she interacts: Who may be allowed to have a situational awareness according to privileges and privacy.
USSP Supervisor	USSP	Being the level of automation high, it is not envisaged the role of "Controller". Nevertheless, it has been envisaged a person who will arbitrate or impose a solution in some cases (in case of escalation required) who may intervene manually imposing ad-hoc solutions or taking over other USSP roles.
Authorization Workflow Representative	Civil Aviation Authority Local Authority ANSP ...	A person having the rights to participate in the authorization workflow (e.g. when local authority/USSP/NAA must express the approval or does not object).
Capacity Authority	ANSP USSP Civil Aviation Authority	A person receiving warning and alerts from the monitoring service Responsible for setting the minimum safe operating conditions that determine the capacity of an airspace or an aerodrome due to safety Responsible for setting noise level limits that limit capacity due to noise footprint and "dose"
Drone Manufacturer Representative	Drone Manufacturer	It is responsible for drone registration and using the system for all other obligations the drone manufacturer must comply (e.g. drone model/characteristics/performance publication).
Airport Operator Representative	Aerodrome Operator	It is responsible for interacting with the system to protect airport perimeter (anti drone) to contribute to the safe integration of drones in airspace, especially in airport vicinity. It will responsible to establish proper coordination with other relevant stakeholders.

Figure 37: Operational stakeholders
Credits: Photo Courtesy of CORUS [35]