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INTEGRATION OF UTM WITHIN THE CURRENT AIRSPACE ARCHITECTURE. IS IT EVEN POSSIBLE?

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Abstract

This paper comprehensively describes the various issues of Unmanned Aircraft Systems (UAS) in terms of their integration into a contemporary and complex system such as Air Traffic Management (ATM). In its introductory part, the paper systematizes and outlines the theoretical knowledge of UAS and categories of airspace sharing entities. However, the main part is devoted to the analysis carried out on the observation of latest proposals of Unmanned Aircraft Systems Traffic Management (UTM), new flight rules as well as state-of-the-art research in several countries throughout the world. The objective of this task is to assess the possibilities, obstacles, and approaches to the integration of unmanned aerial vehicles (UAVs) into the current airspace. The content of this paper is not only informative in nature it but offers concrete explanations, and it may be used as a part of preliminary study for further research in this area.

Keywords

UTM, integration, UAV, ATM, airspace

1. Introduction

The digital age of aviation will change our skies. The number of flights will grow by orders of magnitude. The Airports of tomorrow will be around us, e.g. in our homes and our workplaces, on the roofs of buildings, on top of delivery vans and fire trucks. However, such dramatic expansion is not so straightforward. We must find a way to introduce these aircraft safely. They must co-exist with each other and with future uses that have not been invented yet. It's necessary to redesign airspace in a way that enables innovation, while also prioritising high assurance. The benefits of one flexible architecture – the Internet, for example, is possible only in the online world. There are multiple proposals for modernizing airspace using digital systems. NASA's UAS Traffic Management (NASA UTM) creates a framework for safely managing a growing use of low-altitude airspace. In Europe, the SESAR Joint Undertaking is developing „U-Space“ which opens the continental market for lower altitude drone and aircraft services. Both plans paint a picture of a decentralized, coordinated network of services that safely open airspace to new and exciting uses. Recent developments in battery capacity, autonomy and on-board technology makes operation of completely new kinds of aircraft possible. These aircraft have new shapes, capabilities and roles, which our current airspace system was not designed to handle. Smaller cargo drones can move packages faster and more efficiently to destinations like hospitals, offices and homes. An emerging class of electric vertical take-off and landing (eVTOL) aircraft can transport people around congested cities in minutes, instead of hours. These new vehicles can fly higher or lower than ever before. And because prices will fall to a fraction of today's air operations, they create the potential for massive, wide-scale use.

2. Background and state of the art

The term Unmanned Aircraft System – UAS was adopted by the International Civil Aviation Organisation simultaneously with the British Civil Aviation Authority after it was adopted by the United States Department of Defense and the FAA in 2005 (Jcs.mil, 2019). This term emphasizes the importance of elements other than the aircraft itself. It includes elements such as ground control stations, data links and other support equipment. Recently adopted terms are unmanned-aircraft vehicle system (UAVs), remotely piloted aerial vehicle (RPAV) and remotely piloted aircraft system (RPAS).

2.1. Categories of airspace sharing entities

It is obvious that main users of the today's skies are manned jet airliners flying for commercial purposes and ever-present general aviation airplanes and helicopters. However, this is about to change due to the enormous amount of unmanned aircraft expected to be operating in the next few years.

2.1.1. Commercial aviation

IATA (2019) predicts that airspace will get busier and more complicated as unmanned operations expand and global air traffic doubles by 2036. With up to 25,000 commercial flights in the air during peak times, demand for pilots will triple current numbers and greater ATM automation will be necessary to handle the increased volume.

2.1.2. Helicopters

Helicopters excel when endurance or capacity are important—such as in emergencies, search and rescue, commercial transport, and maintenance of infrastructure. Today's helicopters predominantly use visual flight rules but are increasingly adopting digital systems for navigation and air traffic coordination (NASA, 2018).

2.1.3. General aviation

Private, non-commercial flight covers everything from high-performance business jets and medical transports to gliders and flight trainers (Kazda et al., 2013). Pilots require flexibility in when and where they fly, generally depart without filing a flight plan, and may seldom talk to air traffic controllers, depending on where they fly. In general, the community is cost-conscious, against new equipage mandates, and concerned about privacy, so should only be required to participate in the air traffic system when it is a safety issue. Several groups hold considerable sway, particularly when it comes to imposing taxes or usage fees.

2.1.4. Hobby UAVs

More than 3 million consumer hobby drones were sold worldwide in 2017. Users fly for fun, and most flights are remotely controlled, while some newer drones can automatically follow the user or fly pre-programmed patterns. Hobby pilots are required to stay below 400 feet above ground level in most areas, but this is currently difficult to enforce. Most users are untrained, relying on education from pamphlets or programs like the FAA's Knowbeforeyoufly.org (2017).

2.1.5. Imaging and analytics UAVs

Drones can perform inspections and capture imagery faster, more often, and more safely than terrestrial scanning (Pecho, et al., 2019). This data can be used for everything from construction and agriculture to insurance and disaster relief. Flights can cover a region on a regular schedule or be ordered on demand. These missions can be local or cover long distances (Ažaltovič & Kandera, 2018).

2.1.6. High altitude long-endurance UAVs

Whether they are remotely piloted or fully autonomous, they are able to operate in very high altitudes, above altitudes used by airliners or business jets and for long periods (Bugaj et al., 2019). They could provide services such as sub-satellite imagery and distribution of access to wireless internet.

2.1.7. Delivery UAVs

Four billion parcels were ordered online for home delivery in Europe in 2017, up 28% on the previous year (Ažaltovič & Kandera, 2018). Tomorrow, everything from retail parcels to urgent medical deliveries will be moved by air—from small drones to larger eVTOL transports. Delivering only 1% of parcels this way will create more than 14,000 drone flights every daylight hour across Europe alone, requiring significant airspace management to ensure safety.

2.1.8. Government and military

National and regional governments regularly use airspace for law enforcement and emergency management. They use light aircraft, helicopters, and drones. Military training and operations, meanwhile, use aircraft and drones extensively (Jcs.mil, 2019). It is important that government and military operators receive priority access to airspace when necessary. They should also be able to enact airspace restrictions, define training routes, and mandate other airspace constructs that are essential to public safety and national security missions.

2.1.9. Transport UAVs

Today, light planes and helicopters connect air taxi operators and passengers through platforms like Airbus' Voom and Blade. Air Mobility (UAM) aircraft will take off and land vertically from airports and "vertiports" all over towns and cities for passengers and emergency transport. As the technology becomes more affordable, air traffic will increase hundreds of times over. If just 1% of the 2.2M people in central Paris commute by UAM each day, there will be more than 11,000 flights per hour over the city during peak times as is predicted by Airbus (2019).

2.2. Infrastructure and development

Industries ranging from agriculture to entertainment and media are taking full advantage of the benefits drones offer. However, it's clear that one of the most rapidly growing sectors is infrastructure development which includes construction. This isn't surprising, as their benefits range from on-site safety to a level of project monitoring which wasn't previously possible. The market potential and business case are exemplified by large data processing contracts that exceed EUR 10 000 annually for a single drone used across multiple sites given drones enable routine surveys over large areas in a timelier efficient and cost-effective manner. In the near term, mining is likely to drive significant growth with 7 000 drones expected across around 20 000 quarries and mines that are mostly small (i.e., 15 000 sites have approximately 3 employees). The number of drones in a variety of construction sites is likely to be much larger, estimated at 35 000, especially once drones can operate closer to populated areas (Geospatial World, 2018). The expected operating model within construction is for individual surveyor teams to be allocated a drone. 35 000 drones are expected to be needed to serve a large proportion of over 2 million estimated construction sites in Europe given each team has the ability to serve multiple sites (estimated at 8 per team) that each need support for a portion of the total duration (requirement of 3 months, acknowledging different usage intensities across sites, as part of sites that may last beyond a single year).

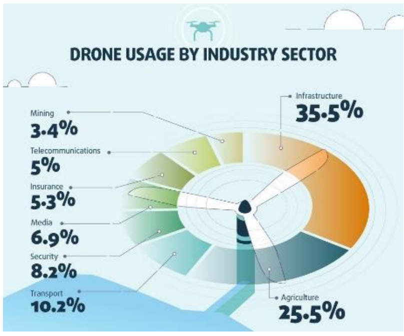

Figure 1: Largest operators of commercial drones. Source: (Geospatial World, 2018).

3. Process of UAS integration

Small UAVs are unmistakably different from aircraft in so many ways, yet they are considered as full-fledged aircraft in most countries. This is perhaps the prime challenge impacting their governance. Few understood how the UAV industry could reinvent itself so dramatically and become so far reaching in every enterprise and field of work. The number of UAVs now flying is mind-boggling. The yearly sales of small UAVs in 2016 have reached 400 000 units in Germany and are likely to reach 1 million in the next year, 2020 (Sesarju.eu, 2019).

Many urban areas including airports and helicopter landing sites and their associated approach/departure paths need to be safe from the interference, as aviation is not without risk and the reputation of UAV technology would be severely affected in the aftermath of a mid-air collision with a passenger aircraft. Also, beneficial civilian applications of the UAS have been proposed, from goods delivery and infrastructure surveillance, to search and rescue, and agricultural monitoring. Currently, there is no established infrastructure to enable and safely manage the widespread use of low-altitude airspace and UAS operations, regardless of the type of UAS. A UAS traffic management (UTM) system for low-altitude airspace may be needed, perhaps leveraging concepts from the system of roads, lanes, stop signs, rules and lights that govern vehicles on the ground today, whether the vehicles are driven by humans or are automated.

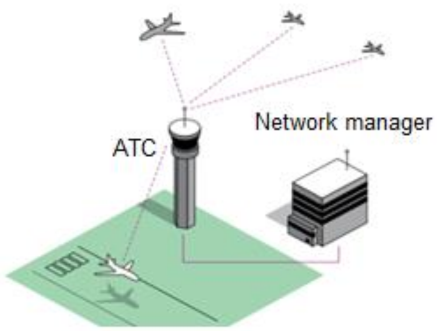

Figure 2: Current ATM system. Source: Authors.

UTM allows the same foundation to serve different needs in different geographies at different times. Regulators can adapt requirements to match their local needs, and operators can select the providers they need to complete their missions. Providers can create, update and deploy their own services quickly. One operator can choose to build, certify and supply its own services, while another may find the same services in a marketplace. Providers will be responsible for coordinating with each other. For unmanned applications to thrive, many stakeholders must come together to advance their respective domains. Advances can be accomplished in phases, with each phase dependent on the previous ones. As UTM shows positive results, there may be technology sharing or increased integration with traditional ATM.

3.1. UTM by NASA

Building on its legacy of work in air traffic management for crewed aircraft, NASA is researching prototype technologies for a UAS Traffic Management that could develop airspace integration requirements for enabling safe, efficient low-altitude operations.

While incorporating lessons learned from the today's well-established air traffic management system, which was a response that grew out of a mid-air collision over the Grand Canyon in the early days of commercial aviation, the UTM system would enable safe and efficient low-altitude airspace operations by providing services such as airspace design, corridors, dynamic geofencing, severe weather and wind avoidance, congestion management, terrain avoidance, route planning and re-routing, separation management, sequencing and spacing, and contingency management (NASA, 2018).

3.2. U-SPACE for Europe

U-space is a set of new services and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones. These services rely on a high level of digitalisation and automation of functions, whether they are on board the drone itself, or are part of the ground-based environment. U-space provides an enabling framework to support routine drone operations, as well as a clear and effective interface to manned aviation, ATM/ANS service providers and authorities. U-space is therefore not to be considered as a defined volume of airspace, which is segregated and designated for the sole use of drones. U-space can ensure the smooth operation of drones in all operating environments, and in all types of airspace (in particular but not limited to very low-level airspace. It addresses the needs to support all types of missions and may concern all drone users and categories of drones (Sesarju.eu, 2019).

Key functions are provided by U-space Service Providers (USP) which may be required to exchange certain information and coordinate through a SWIM system. They may also communicate with a U-space system manager—similar to the Single European Sky's current network manager. This acts as a centralized coordinator in a manner much like NASA's FIMS, as well as manages traffic. Other providers are responsible for non– safety–critical services, as well as data on weather and terrain (Airbus, 2019).

3.3. UOMS in China

The UOMS is an integrated system serving as a Chinese solution of offering air traffic service to UAS. It cooperates with GAFS system and communicates with current ATM system. Except the role in air traffic service, UOMS also interacts with other UAS management systems developed for public or military purpose. In order to integrate unmanned aircraft into the ATM, the proposal is divided into two levels. On the strategic level, the priority should be solving airspace classification and configuration problems, while on the tactical level it should be providing different air traffic services to different users (Butterworth-Hayes, 2019).

Current ATM should transmit to UOMS the flight path of the transport aircraft in terminal (approach) control area, in order to provide the basis for the required task approval and real-time collision risk alarm for UOMS. Due to natural physical isolation, ATM does not need to transmit the en-route flight path of the commercial flight. UOMS should transmit to current ATM all flight plans (except open operations) received by UOMS and real-time UAS flight data, including real-time latitude and longitude, altitude, speed, course, flight identification, etc.

3.4. JUTM

The name is derived from the initial of Japan Unmanned System Traffic & Radio Management Consortium. In the United States, UTM activities for unmanned aerial vehicles are being conducted mainly by NASA, while JUTM is examining land and air unmanned aerial vehicles and also including radio wave management. Their main goal is to create a new, industrial „Drone Innovation Space" and promote the ongoing revolution in aviation. They also aim to incorporate Japan's systems and technologies to the international standard that NASA'S UTM project is pursuing (Jutm-imgtransuv.org, 2018).

This system is being built by the JUTM (2018) and a national UTM project founded by New Energy and Industrial Technology Development (NEDO). It comprises one FIMS, several UASSP providers, a layer of SDSP providers, and operators. FIMS manages all flight plans, handles emergency alerting and provides avoidance instructions. The UASSP sits between FIMS and each operator. JUTM started demonstrations in 2017. Individual systems developed under NEDO will be demonstrated during 2018, with first full system demonstrations in 2019 and implementation slated for the 2020s.

3.5. Global UTM Association

The Global UTM Association (GUTMA) is a non-profit consortium of worldwide Unmanned Aircraft Systems Traffic Management stakeholders. Its purpose is to foster the safe, secure and efficient integration of drones in national airspace systems. Its mission is to support and accelerate the transparent implementation of globally interoperable UTM systems. GUTMA members collaborate remotely. The purpose of this association is to:

- identify actions to be taken to safely, securely and efficiently integrate UAS into national airspace systems,
- draft and distribute an interoperability blueprint for traffic management of UAS,
- collaborate with regulators and other stakeholders worldwide to identify standards, as well as scalable and compliant technical solutions to the development of UAS traffic,
- instigate and facilitate partnerships between manned and unmanned users of the airspace,
- and engage with other associations and groups facing similar challenges.

The Association may engage in all activities and take all actions necessary and appropriate to carry out the above objectives (Global UTM Association, 2017).

Among their publications, the UAS Traffic Management Architecture. This document describes the overall high-level UTM architecture. It considers all types of UAS operations (VLOS, EVLOS and BVLOS), and covers the needs of both RPAS (piloted) and autonomous unmanned aircraft. The scope of the UTM described in this document will focus on a UTM solution for UAS operations in very-low-level airspace. The document also addresses the requirements for all phases of the flight and is identified as a common architecture with interfaces with external systems. This will serve as a baseline to define the standard interfaces.

3.6. MyDroneSpace by IXO Systems

In more congested airspace of countries like Hungary a Poland, it is not yet possible to integrate a delivery service on such a scale as in Rwanda. Civilian hobby use is so far the main goal of companies such as R-SYS Ltd. with their IXO System which represents a complex solution for airspace users and providers who look for a product that seamlessly integrates information on manned and unmanned aircraft operations and provides real-time aeronautical information for all airspace users. The system applies the latest regulations to flight planning, airspace usage conflict calculation, RPAS flight validation/clearance processing, manned/unmanned aircraft management, or aeronautical data provision. IXO SYSTEM presents a powerful and multi-platform solution which satisfies requirements of ATM integrated and interoperable system while it emphasizes timely distribution of accurate aeronautical data. It aims to:

- provide information via web interface to various users within and outside ANSP network,
- facilitate the NOTAM Office daily operations, to maintain and exchange NOTAM information,
- grant demands of ANS providers,
- publish and update AIP information
- provide ARO with integrated flight planning information,
- provide RPAS (Drone) flights management tools. (R-SYS, 2018)

Figure 3: Requesting flight zone for an activity. Source: (R-SYS, 2018).

3.7. DroneRadar

A rapidly growing number of Unmanned Aerial Vehicle operations have caused major concern over flight safety. Air Traffic Management institutions, like ATC, FIS are finding it difficult to track such operations as the majority of those are conducted by amateurs with no aviation background and little or no knowledge of both airspace structures and flight rules. The aim of the DroneRadar is to vastly improve airspace safety by providing a simple, available to all solution to performing, monitoring and integrating UAV operations with the manned aviation flow in European airspace.

DroneRadar (2016) is a non-restrictive, mobile, cloud-based platform which allows the precise registration and monitoring of drone operations via social sourced information. The system is based on simple concepts easily understood by amateurs but at the same time provides sophisticated functionality for Air Traffic Services and for professional users such as military and governmental institutions. Up to now there has been no means or concept of integrating such operations into the mainstream ATM flow, which would allow for creating awareness of them and their monitoring. DroneRadar is the first, ANSP integrated system platform allowing for such integration.

Clearly, DroneRadar is a solution many UAV operators and ATM institutions have been waiting for and has enormous potential for structuring procedures needed to integrate UAV operations into the ATM flow. Detailed analyses of the collected statistics may be used for risk assessment and may be a great input for SMS (Safety Management System) analyses. DroneRadar confront all regulations which apply to FIR and present them in easy to understand way, to all users (professionals and amateurs). The service is fully operational in Poland since December 2015.

4. Findings and recommendations

In order to support the safe integration of unmanned aerial systems into current airspace, several recommendations and findings have been made. Today's Air Traffic Management systems are complex and consist of many different functions. They are provided in a one-to-many fashion, through a central entity such as a control centre, and the services are deployed as a solid framework. Functions include the acceptance and approval or rejection of flight plans, tracking of aircraft, providing guidance and separation services to pilots, and handling emergency situations. This approach works well for existing aviation needs, which are well defined and grow predictably. New traffic management systems will perform many similar functions. However, the way these are delivered will need to be different because of the radical increase in traffic density and the changes in vehicle performance, onboard automation, and sensing technology. For example, while most commercial flights are planned (in advance) and follow regular schedules, air taxi and cargo missions can be requested just minutes before take-off. In urban environments, traffic densities will be far higher, with vehicles much closer to each other, and to obstacles. The diversity of operations means the traffic management system must be able to cope with aircraft that have radically different characteristics sharing the same airspace.

Estimates show that the growth of commercial air traffic is already exceeding the capacity of a human-cantered system — and that is only for human piloted flights. The expected growth of unmanned and self-piloted operations will increase traffic by several orders of magnitude. To handle this dramatic growth, air traffic management must shift to a more scalable model: a digital system that can monitor and manage this increased activity (Airbus, 2019).

In operation, this implies UAV are no longer required to talk only to a particular entity, such as a designated ATC. Instead, UAV can communicate easily with their service providers of choice, who are held to relevant safety/security, and performance requirements by the aviation authorities and harmonize with the rest of the network to make optimal decisions based on specific flight objectives. Human ATC, meanwhile, will become airspace supervisors, dedicated on oversight, safety, and security.

4.1. Establishing new flight rules

Existing flight rules and airspace services limit or prevent drone flights. Drone traffic has a greater diversity of landing locations: not just airports, but vertiports and delivery platforms that could be on buildings, in backyards, and even on vehicles. These landing locations are spread throughout a region rather than concentrated at an airport— indeed, every home could be a potential landing site. The current system of approach and departure routes needs adapting for drones and helicopters. The in-flight phase can vary widely, too. Infrastructure inspection and emergency response can involve hovering near a ground location at a low altitude point. Agricultural missions involve low-altitude flights back and forth over a plot of land to measure soil or plant conditions. New kinds of missions require new kinds of traffic management.

The current air navigation system is largely organized around paths that travel between waypoints, increasingly defined ad-hoc in 3-D by satellites. Drone flights performing missions in lower density airspace could use free routing, with fixed routes, corridors, or other constructs to avoid conflicts, obstacles, or areas too dense for safe operation. In high-traffic areas like urban centres, airspace structure, infrastructure, and procedures may be required to enable safe operations. A delivery warehouse, for example, has many drones approaching and departing, requiring coordination to operate safely. Procedures can define a safe route through an otherwise sensitive space, such as crossing over an airport. Other procedures can organize safe routes between buildings in an urban core, with special navigation aids to ensure high-precision guidance in complex environments.

Aircraft today use Visual Flight Rules (VFR) or Instrument Flight Rules (IFR). These are essential for maintaining safe separation distances between aircraft to prevent collisions (Kovacik et al., 2019). Complying with these rules limits operations for drones and helicopters and does not allow for the introduction of new capabilities like automation in a safe and extensible way. Airbus (2019) indicated new flight rules to be established — for example, Basic Flight Rules (BFR) and Managed Flight Rules (MFR). BFR would cover flights that operate independently. They take full responsibility for their safety, routing, and separation from other air traffic. MFR will apply to flights that coordinate their trajectory with a traffic management service and follow its guidance to maintain separation. Traffic management services direct flights using MFR and monitor changes in the airspace, such as temporary restrictions or weather conditions. Flights receive control instructions to keep operations within acceptable risk tolerance thresholds. Real-time two-way communications report position and status so that traffic managers can coordinate with their aircraft. Around airports, ATM and UTM services work together. For example, they coordinate the direction of local traffic flows between fixed wing aircraft and unmanned drones at local airports based on weather conditions. Traffic management services provide basic information to pilots and autopilots about conditions in the airspace, regulation, and nearby traffic. Managed aircraft use this information as input for tactical self-separation and collision avoidance. The same general traffic information is useful to any pilot to improve their flight planning and in-flight situational awareness.

5. Conclusion

The main aim of this paper was to assess options and approaches to UAS integration and summarize by these means the knowledge of the process of gradual, safe integration of unmanned aerial systems into airspace. Based on the results of the analysis of the current state of the art and the adapting legal regulations, we have identified specific options, approaches and means of determining this process.

When analysing the data provided by senior field studies, conferences and scientific articles, we discovered that there is now a tremendous amount of effort to make UAS integration as fast and secure as possible. Research coupled with this paper also enabled the processing of specific strategies such as the creation of air corridors for drones of different categories and the possibility of applying these strategies. Based on these findings, it can be determined in which cases it will be best to apply the selected strategy or approach. In the case of the integration process, it is also necessary to follow this process in other, especially neighbouring countries, and to ensure the highest level of standardization and cooperation, which will significantly simplify international UAV flights in the future. We expect that in the decision-making process of introducing new regulations for UAVs. So, after that it will be possible to answer our question responsibly.

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