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Drone Information Service Requirements for U-Space

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***Abstract*—The work presented in this paper is part of the SESAR Horizon 2020 exploratory research project DREAMS, which analyses operational and technical aspects of drone Aeronautical Information Management (AIM) for Europe's Unmanned Traffic Management system, U-Space. The main objective of DREAMS is to analyse the present and future needs of aeronautical information for future drone flight. The present paper investigates the required information services for achieving safe drone traffic operations in very low altitude airspace. The required drone information services were identified by conducting a comprehensive gap analysis on existing information services from manned aviation and current U-Space service providers in line with drone operator and user requirements. The latter was amalgamated from a comprehensive online survey, an identification of reference scenarios and high-level U-Space services. This research study indicated information gaps in seven key categories: flow management, meteorological, environment, flight, surveillance, communication and drone (vehicle) information. Finally, solutions to bridge these gaps are proposed in this paper.**

***Keywords*—Drones, U-Space, UTM, Drone information, DREAMS, Geofencing, Geocaging, Geovectoring.**

I. Introduction

For the past two decades, drones have mainly operated as intelligence gathering tools to support military missions. However, drones have now gathered significant interest in civil and commercial applications such as high-definition aerial-image capture and delivery of time-sensitive medical supplies as well as commercial packages in urban and rural areas [1], [2]. With the demand for drone services steadily growing, and with the potential for drones to bring about economic and social benefits [2], [3], in 2016, the Single European Skies ATM Research (SESAR) initiated Europe's Unmanned Traffic Management (UTM) program, U-Space, in order to realise these potentials [4]. The goal of U-Space is to enable complex drone operations with a high-level of automation in urban and rural environments [4], [5], [6].

To help define Europe's UTM, several exploratory research projects were launched under the U-Space umbrella. The work presented in this paper is the research conducted as part of the DRone European AIM Study (DREAMS) project, one of several exploratory research projects related to U-Space. The DREAMS project aims to fill the gap between the existing information used by traditional manned aviation and the needs of the new unmanned aviation in order to support safe drone operations at Very Low Level (VLL) altitudes, i.e., altitudes not higher than $500ft$ above ground level, in urban environments [7]. For this purpose, the DREAMS project conducted an extensive survey analysis, identifying reference scenarios with respect to high-level U-Space services, and performed data and service availability assessments.

In this work, we identify the gaps between existing aeronautical information and the data requirements from drone operators and its users. The identified information service gaps for future drone operation will then be tackled by proposing solutions to fill these gaps. These identified information service gaps for future drone operations are critical for achieving safe drone operations in VLL airspace.

The remainder of this paper is organized into six sections. Section II provides an overview of the high-level U-Space services. Next, Section III describes the drone user and operator requirements and the methodology undertaken to identify such demands. This is followed with the identification of existing manned aviation information in Section IV. The gap analysis and the proposed solutions to bridge the identified drone information service limitations are described in Section V. Finally, a summary of the main conclusions is outlined in Section VI.

II. U-SPACE: UNMANNED TRAFFIC MANAGEMENT SYSTEM FOR EUROPE

U-Space is a set of new services developed for safe, efficient and secure integration of high-density of drones to the current airspace system [4], [5]. These services rely on a high level of digitalization and automation of functions both on-board drones and on the ground-based environment. U-Space aims to provide an enabling framework to support and foster the growth of drone operations in a sustainable way. This will be achieved by deploying U-Space services in four stages [4]:

- **U1**: U-Space fundamental services: E-registration, E-identification, Pre-tactical geofence;
- **U2**: U-Space initial services: Tactical geofencing, Tracking, Flight planning, Strategic de-confliction, Hyper-local weather information, Drone aeronautical information management, Traffic information;
- **U3**: U-Space advanced services: Dynamic geofencing, Dynamic capacity management;
- **U4**: U-Space full services: New services expected to arise during unfolding of U3.

III. DRONE USER & OPERATOR DEMANDS

To determine the drone user and operator requirements for future drone flight operations, first, a comprehensive survey analysis which was addressed to European drone users and operators, as well as authorities and manned aircraft pilots was conducted. Thereafter, a detailed reference scenario identification analysis was performed, to add context to the survey and also to capture any gaps in the present information services.

A. Survey analysis

The goal of the survey was to understand the critical information needs of two main cohorts of stakeholders, i.e., drone operators and users on the one hand, and manned aviation pilots and authorities on the other hand, with respect to current and future drone operations. The survey was made available by means of a web questionnaire which was presented on the DREAMS website between February and April 2018. The purpose of this survey was to support the following activities of this study:

- Identification of stakeholder needs;
- Identification of target scenarios for the study;
- Recognition of key information to unlock future Beyond Visual Line of Sight (BVLOS) operations and information that would enhance drone flight operations;
- Assess the minimum dataset for drone information required to operationalise U-Space.

To accomplish this, a total of 8 multiple choice questions were posed to the two cohorts, and each question presented the possibility for the survey participants to add recommendations. This survey was distributed to European drone communities via social media sites, specialized journals and magazines, drone operator associations and drone pilot training centres. In addition, the survey was also presented to experienced personnel at relevant authorities such as Eurocontrol and research institutes.

The survey received 153 responses in total, of which 108 were from the drone user and operator category (cohort 1) while the remaining 45 stemmed from the authority and manned aircraft pilot category (cohort 2). The results from the survey are described in Table I. From this analysis it was seen that both cohort agreed to aerial image capture being the most prominent application in the future. This may be because the respondents currently employ drones for aerial photography. Moreover, there is also a consensus between the cohort with respect to the information service demands as seen in rows 4-8 in Table I. These identified information service needs will be analysed in this paper in order to find potential solutions.

TABLE I
WEB QUESTIONNAIRE RESULTS GATHERED FROM DRONE OPERATOR & USER (COHORT 1) AND MANNED AIRCRAFT PILOTS & AUTHORITIES (COHORT 2)

Survey intent	Cohort 1	Cohort 2
Typical drone applications	Aerial image capture, inspections, agricultural use	Aerial image capture
Typical operational altitude	300 to 400ft	0 to 200ft
Urban environment flights	Occasional flights	High-density
Flight operations data	Obstacle data, hyperlocal weather, detailed 3D elevation, Geofenced areas, Real-time traffic position data, Population density of overflown areas, bird warning, Separation rules	Geofenced areas, obstacle data, real-time traffic position data, separation rules, hyperlocal weather
Flight operational risks	Presence of obstacles, presence of birds, poor GPS/GNSS signal, loss of video datalink, sudden wind gusts, loss of communication and control, flying over urban areas, presence of other traffic	Presence of obstacles, presence of other traffic, loss of communication and control, poor GPS/GNSS signal, flying over urban areas
Time demanding pre-flight phase activities	Flight permission, mission planning, mission verification, gathering hyperlocal data, gathering obstacle data	Flight permission, mission planning, securing area for flight, gathering obstacle data, gathering hyperlocal data
Real-time data for BVLOS flights	Real-time traffic position data, location of birds (uncontrolled traffic), temporary geofenced areas, active NOTAMs (Notice to Airmen), hyperlocal weather, detailed 3D elevation map, population density of overflown areas	Temporary geofenced areas, active NOTAMs Real-time traffic position data, hyperlocal weather, location of birds, population density of overflown areas
Mandatory BVLOS flight planning data	De-conflicting flight plans, active NOTAMs, GNSS availability, hyperlocal weather, obstacle data, temporary geofenced areas	Active NOTAMs, de-conflicting flight plans, temporary geofenced areas, hyperlocal airspace data, obstacle data

B. Scenario identification analysis

A set of operational (both current and future) scenarios were identified such that it encompasses all U-Space deployment levels. This was accomplished by using a bottom-up approach which aims at identifying future drone applications and missions, the required information services and its U-Space alignment. As a result, eleven scenarios were identified as shown in Table II alongside its respective U-Space deployment level and its associated flight phase.

1) Electronic registration: During the E-registration process the drone operators/users will provide a set of key information such as name of user, valid contact details, valid user identification, drone model and serial number in order to receive an unique U-Space identification number and permission to fly. The challenge we foresee here is the cumbersome process of providing the above key information manually.

2) Concurrent operations: The scenario of concurrent operations is related to the U-Space services of pre-tactical geofencing, strategic de-confliction, flight planning management and weather information. This scenario involves pre-flight and execution phases with the aim of identifying requirements and challenges with respect to two or more drone flights in close proximity. The requirements identified in this particular scenario involve hyperlocal weather information, contingency measures, horizontal and vertical separation guidance, altitude allocation and capacity management of the airspace.

3) Territory control: This scenario deals with U-space services of E-identification and monitoring and tracking of flights. This scenario was developed in order to identify requirements for situational awareness of the airspace. The requirements generated by this scenario involve fast and easy identification (real-time) of drones by law enforcement authorities and situational awareness of traffic in the airspace.

4) Cooperative geo-tagging: The particular use-case for this scenario includes ground obstacle mapping to create obstacle awareness for drone flights. Such a scenario is expected to associate with the U-Space services of pre-tactical geofencing, tactical geofencing, flight planning management and tracking. The requirements for this scenario involves uninterrupted video data-link connection and information management of mapped obstacles.

5) Controlled traffic zone crossing: The specific use-case for this scenario is the request for crossing a controlled airspace by the drone operator, and it envisions to make use of the U-Space services of flight planning management and procedural interface with air traffic control. The information demands for this scenario entail ATM/UTM interface boundary data.

6) Long-range operations: This scenario relates to BVLOS operations. The particular U-Space services for this scenario include weather information, drone aeronautical information management, traffic information, monitoring and tracking. To accomplish this scenario the following information services are needed: obstacle information, hyperlocal weather, traffic information and uninterrupted communication signals.

7) De-confliction management: The de-confliction management scenario encases the use of tactical geofencing, flight planning management, drone aeronautical information service and strategic de-confliction from U2 of U-Space. We expect this scenario to be realised with the requirements of timely situational awareness of advisories such as Digital NOTAMs and real-time updates of tactical geofencing measures.

8) Emergency management: This scenario involves the specific use-cases of emergency landing and loss of command and control. The scenario expects to incorporate U2 services of emergency management, tactical geofencing, flight planning management, and drone aeronautical information management. To circumvent such a scenario, we identified three information service requirements that includes the provision of situational awareness with respect to the drone battery status, guidance on emergency landing procedures and coverage areas of GNSS signals.

9) Capacity management: The Scenario of capacity management deals with high-density drone traffic. This scenario expects to involve the use of U2 and U3 U-Space services: flight planning management, dynamic capacity management, and dynamic geofencing. However, our scenario analysis indicated additional requirements for capacity management. These additional requirements include: urban airspace intrinsic and strategic conflict risk mitigation [16] and first/last $50ft$ of operations guidance. These requirements can be viewed as gaps in the existing information for drones and thus, solutions to these will be presented in Section V of this paper.

10) Reconnaissance and personal mobility: These two scenarios relate to future applications of reconnaissance (intelligence gathering) and personal air mobility such as flying air taxis. Both scenarios expect to employ U-Space information services of flight planning management and collaborative interface with air traffic control to enable such operations. However, we expect these services to be insufficient for enabling safe operations and thus additional requirements were generated as a fail-safe measure. The additional requirements include the management of video imagery from reconnaissance mission with respect to local privacy regulations and noise assessment. The remaining requirements are equal to the ones mentioned for capacity management.

The above description of the identified operational scenarios has indicated several key drone operator and user requirements to achieve safe operations. These requirements will be further discussed in Section V.

IV. EXISTING AERONAUTICAL INFORMATION SERVICES

This section summarizes the analysis performed to identify current information services in manned aviation that can potentially be used, or that is already defined in U-Space. Throughout this process, several information services were derived from air navigation initiatives such as SWIM services [9] and open-source aviation services. Similarly, a study was conducted on existing UTM/U-Space service providers. Our analysis on the latter proved useful in identifying relevant U-Space services that already exist.

TABLE II
IDENTIFIED SCENARIOS WITH RESPECT TO U-SPACE DEPLOYMENT LEVEL AND ASSOCIATED FLIGHT PHASE

Scenarios	U-Space level	Flight phase
Electronic registration	U1	Planning
Concurrent operations	U1, U2	Pre-flight, In-flight
Territory control	U1	In-flight
Cooperative geo-tagging	U1, U2	Planning, Pre-flight, In-flight
Controlled traffic zone crossing	U2	Planning
Long range operations	U2	Planning, In-flight
De-confliction management	U2	In-flight
Emergency management	U2, U3	In-flight
Capacity management	U2, U3	Planning, Pre-flight, In-flight
Reconnaissance	U2	Post-flight
Personal mobility	U2, U3	Planning, Pre-flight

A. *Manned Aviation Information*

With the implementation of SWIM, existing manned aviation information services are currently undergoing a paradigm shift in the management of aeronautical information which will enable its stakeholders to share concise information in a timely manner [9]. The type of information shared on the SWIM network includes aeronautical, flight trajectory, environment, meteorological, air traffic flow, surveillance, and capacity and demand information services [9], [11], [10]. Six main elements from the above list of information services were extracted and surveyed to determine services that could potentially complement U-Space. These six manned aviation information services [9] are listed below:

- Airport information services which includes airspace capacity, performance and information management;
- Planning, performance monitoring and analysis information which entails strategic, operations, strategic event planning, air traffic demand data, capacity assessment and planning;
- Flow and capacity management i.e., strategic, pre-tactical and post-operations air traffic flow and capacity management;
- Flight data services i.e., reception and distribution of real-time airport, air traffic control, surveillance data, weather information and disruption and crisis management information;
- Flight planning information services which encompasses repetitive flight plan processing, flight plan filing and management, and performance-based navigation implementation support;
- Communication services which includes surveillance tools such as the air traffic management surveillance tracker and the surveillance analysis support system for ATC centres tools e.g., GNSS availability tool.

The above information and services are primarily supplied by Air Navigation Service Providers such as Eurocontrol [10]. Our analysis of the above inventory of manned aviation information services indicated that a majority of these services cannot be leveraged to unmanned aviation due to the specific requirements from drone operators and users.

Furthermore, we surveyed key open-source information services from manned aviation consisting of surveillance, meteorological, and terrain and obstacle information. The services supplied by the open-source surveillance providers enable users to extract real-time positioning information of manned aircraft traffic. Our analysis, however, indicated that there is no certainty in real-time positioning information at very low level altitudes. This disparity in the surveillance information could pose a risk to drone flights. Similarly, there is a disparity in meteorological information since drones require hyperlocal meteorological information. This is because weather factors such as wind speed are highly dependent on local features such as obstacle density, land cover, and elevation of obstacles. Our analysis showed that specific countries in Europe do promote the availability of hyperlocal weather information, however, this is limited to regions within a city. This should be expanded to include the availability of weather information to the 'street' level. Until such information is available, the above service can be used to partially fulfil U-Space U2 service. In terms of terrain and obstacle information, the current processes for origination of obstacle data involve a burdensome regulatory framework for assessment and coordination with aviation authorities. Therefore, new entrants such as drones will place additional pressure on the existing framework. As a result, this calls for innovative methods to be sought for digitizing the urban landscapes and thus supplying this information to U-Space.

B. *Unmanned Aviation Information*

Several commercial start-up companies such as Unifly, AirMap, and Altitude Angel, have launched platforms that feature U-Space services. Our survey indicated the provision of U1 and (partial) U2 services by these start-up companies:

- Flight planning and validation
- Local weather information
- Mission planning
- Geofencing
- NOTAM advisory
- Local rules and regulation awareness
- Remote identification
- Geospatial data
- Real-time tracking and monitoring of unmanned traffic

To fully achieve the services and requirements of U2, additional advanced services such as hyperlocal information is required. More importantly, there is a need for a centralised body for the assurance of the quality of information provided by these entities. We also expect problems to develop with respect to the liability of drone operators with the use of such services. Since these entities are competitive by nature, it may also create issues on the interoperability of the services and the consistency of the information provided. We expect a harmonised drone information service such as U-Space to overcome the above challenges.

V. Gap Analysis

This section is aimed at identifying the information gaps required for achieving safe drone operations in VLL urban airspace. This is done by comparing existing information services from manned aviation and UTM service providers against the requirements derived from drone operators and users and the standard U-Space services. Table III describes the identified information gaps.

TABLE III
DRONE INFORMATION SERVICE GAPS FOR U-SPACE

Information categories	**Information service gap**
Flow management	Urban airspace capacity management High-density traffic management De-confliction management Congestion management Urban airspace intrinsic and strategic conflict risk management First/last $50ft$ operations guidance Hyperlocal airspace data Dynamic geofencing
Meteorological	Past, present, future hyperlocal weather data Sudden atmospheric warning: hyperlocal wind gusts
Environment	Permanent obstacle data Non-permanent obstacle data Geometrical (height and dimensions of obstacles) data Population density of overflown areas Advisory of uncontrolled traffic
Flight	Flight planning assistance Flight risk analysis Optimal altitude allocation Vertical separation guidance Horizontal separation guidance Real-time telemetry Contingency management Emergency management
Communication	Hyperlocal GNSS and 4G/5G coverage map ATC-Drone operator/user communication datalink U-Space instant message service High-quality video datalink Authorities datalink
Surveillance	Real-time unmanned traffic data Digital NOTAM management Drone incident support Traffic monitoring (state and intent information)
Drone	Vehicle performance characteristics Vehicle specifications Vehicle serial number

A. *Proposed solutions to gaps*

The above comparison on existing and required information services for safe drone flight in low altitude airspace indicates several key gaps for the following information service categories:

- Flow management information
- Meteorological information
- Environment information
- Flight information
- Communication information
- Surveillance information
- Drone information

The gaps for the above list of information services will be explained here. Notably, solutions to close these gaps will be proposed in this section.

1) Flow management: The flow management information gaps identified in Table III shows that there are several major gaps to be addressed before safe drone operations in VLL airspace can be made feasible. The first two data services in the flow management list are linked to the challenge of managing high-density drone operations in dense, congested, very low urban airspace.

The de-confliction management information gap, is partially covered by current UTM service providers using de-conflicted flight plans. In addition to this, on-board Conflict Detection and Resolution will be required to resolve remaining conflicts that arise due to deviations from the flight plan and uncertainties. From the perspective of information management this requires communication of relevant aircraft states (position, speed, intent). Proposed solutions could employ, for instance, Automatic Dependent Surveillance Broadcast (ADS-B), FLARM, or cellular network communication for data transmission of states, position, speed and intent.

The information gap on congestion management, is crucial for ensuring that the airspace does not become saturated. In addition to airspace measures to maximise capacity, the total number of instantaneous airspace users should also be managed. The proposed solution would be to introduce a form of surge/dynamic pricing as a congestion management measure.

To support the envisioned high-density operations, recent studies have shown that it can be advantageous to, in addition to separating traffic using geocaging, also impose location-specific traffic alignment restrictions [12], [16]. Using mathematical combinatorics it can be shown (using Equation 1) that for a given volume of airspace, increasing the number of vehicles in this airspace quadratically increases the probability of conflict in this airspace:

$$CR = \frac{1}{2}N(N-1)p_2 \tag{1}$$

Here, CR refers to conflict rate, N indicates the number of aircraft, and p_2 is the probability that any two aircraft in this airspace meet each other. This mathematical relationship has been validated by numerous simulation studies [12], [13], [14].

When looking at the above Equation, it can be seen that the rate of conflicts can be reduced either by reducing the possible number of combinations of aircraft that can meet each other, or reducing the probability of conflict of the possible combinations, indicated by the need for urban airspace intrinsic and strategic conflict risk management. The former is achieved by methods that separate aircraft from each other, such as geocaging. For the latter it has been shown that a major factor contributing to conflict probability p_2 is the average relative speed, or closure rate between vehicles in an airspace [16]. An airspace constraint (either intrinsic through airspace design, or strategic as part of dynamic flow/capacity management) that imposes some degree of alignment of traffic is therefore a second effective measure to reduce conflict probability and increase safety and capacity of urban aerial operations. This can be incorporated in an information protocol using the concept of geovectoring, which provides a 'language' to specify allowable speeds and headings in a given part of airspace, to act as a logical complement to geofencing and geocaging [16]. Geovectoring can be applied as a static or a dynamic property. The former will need to be defined as a part of the navigation database while the latter will require a data-link protocol which allows for changing the area and speed vectors dynamically [16].

Another observation that can be made from the above equation, is that if this task load is distributed over the vehicles by decentralizing the separation task, the quadratic relation becomes linear [15]. In other words, for very high densities, as envisioned for urban airspace, centralised de-confliction might not be feasible anymore. In this case, geovectoring aides in reducing the conflicts by still having an organised airspace without the need for submitting flight plans.

Therefore, the proposed solutions for the urban airspace intrinsic and strategic conflict risk reduction gap includes the implementation of geovectoring in U-Space as a measure to manage high-density traffic capacity and the provision of a data-link protocol for information exchange and information for dynamic geovectoring.

The flow management information gap, first/last 50ft of drone flight operation, is assumed to be the most challenging phase of the drone flight [17] due to the presence of dynamic obstacles, static obstacles, uncertain turbulent hyperlocal winds, microburst, failures and contingencies, lack of manoeuvrability, degraded GPS signals etc. This becomes more prominent at high traffic densities. Therefore, this information gap in how to tackle the first/last 50ft of operations for drones will need to be addressed. The following solutions are proposed: investigate the use of intrinsic airspace constraints and dynamic geovectoring for the first/last $50ft$ of operations.

The seventh flow management information gap relates to hyperlocal airspace data i.e., airspace data on a well-defined smaller geographical area compared to a local area. This is similar to Google Street View in which flight planning can be facilitated by getting acquainted with the surrounding environment. Moreover, hyperlocal airspace data may also include geofenced areas on a hyperlocal level i.e., geofencing of a single street compared to an entire neighbourhood. This would benefit the capacity of the airspace. Potential solutions would be to extend Google Street View concept to $500ft$ and augment it with airspace data and manage hyperlocal airspace information with respect to integrity, resolution and accuracy.

The last identified gap for the flow management information category is dynamic geofencing. Dynamic geofencing data service is partially provided by UTM service providers. However, this the service is limited. For example, construction cranes are not geofenced in a timely manner. Moreover, dynamic geofencing can also be employed to confine drones to allowed airspace. A proposed solution to this would be to investigate the use of geo-tagging to 'geo-mark' potential hazardous obstacles and areas, investigate the use of crowd sourcing information on dynamic obstacles, and establish a governing body to manage information and to ensure integrity of dynamic geofencing data.

2) Meteorological information: The challenges for the two identified gaps in Table III include the lack of hyperlocal data points which is mainly due to the absence of meteorological sensors and other data extraction methods in hyperlocal geographical areas. From our analysis, it was seen that hyperlocal precipitation forecasts and severe weather alerts, critical for drone operations, are only available in US, UK, Canada, Germany and Norway. An important issue is the absence of hyperlocal wind alerts i.e., wind gusts on a 'street' level. This is especially required for urban operations. Hyperlocal features such as dense buildings and terrain play a fundamental role in generating uncertain wind vortices. We predict the latter to be hazardous to drone flights especially at high-density traffic situations since it may constrain capacity.

Proposed solutions to this issue would be to install meteorological data gathering sensors at a hyperlocal level for hyperlocal information capture, crowd source hyperlocal weather information, scale and extrapolate hyperlocal weather information from Germany and Norway to remaining European states, and provide minute-by-minute per hyperlocal weather information.

3) Environment information: The challenges mentioned in Table III with respect to insufficient geometrical information on permanent and non-permanent obstacles requires urgent and immediate attention.

In aviation, an obstacle is defined as all fixed temporary or permanent and mobile objects that presents a potential hazard to the safe passage of flight [8]. Three types of obstacles exists [8]: point obstacles (e.g. masts, antennas, etc.), line obstacles (e.g. high-voltage cables, cable installations, etc.) and polygon obstacles (e.g. buildings, large vegetation area, etc.).

In [8] the authors indicated that the above challenges should be tackled with respect to data quality and data origination.

In addition, the paper [8] presented preliminary obstacle requirements of $1m$ accuracy (both horizontal and vertical), a resolution of $1m$ with 95 percent confidence level [8]. Achieving the above requirements will improve safety and thus increase the capacity of the urban airspace [8].

On the other hand, drone operator/user awareness on population density of overflown areas and advisory of uncontrolled traffic such as migrating birds need to be addressed, as they present severe safety concerns for both the drone operator/user and to third parties.

To tackle the above gaps in environment information management for drone operations, we propose the following solutions: collaborate and coordinate with relevant communities interested in geodetic information such as CityGML, 3D model and Building Information Management (BIM) community [8], provide a tool for computing population density of overflown areas from aggregated population databases e.g. World Bank Organisation, exploit the use of on-board drone imagery devices to provide awareness on uncontrolled traffic such as a flock of migrating birds. This form of technology can be defined as Drone to Everything (D2X), which is similar to the connected cars concept seen in modern cars for sharing real-time driving data and, explore the use of on-board drone imagery devices to provide situational awareness on non-permanent obstacles such as cranes.

4) Flight information: The flight information services mentioned in Table III are critical for safe drone operations in low altitude airspace. In this regard we prescribe a set of proposed solutions. To tackle the first gap for drone flight information, we propose a solution that assists drone operators in selecting an optimal flight route instead of an arbitrary route selection process. Next, there are several flight risk associated with drone flight e.g., the risk of air shows, aggregation of large gatherings of urban inhabitants etc. Flight risk information pertaining to this needs to be communicated via a digital NOTAM for situational awareness.

Moreover, the information gap of optimal altitude allocation can be solved by means of an optimal altitude allocation decision-engine. This tool should provide information with respect on where to fly, i.e., to fly above or between buildings, and it should be assessed and optimised with respect to key decision variables such as traffic density, obstacle density, trip distance, hyperlocal winds, payload weight, battery capacity, etc. Similarly, vertical and horizontal separation guidance should be provided as a function of the airspace capacity instead of presenting static separation requirements. This is expected to increase airspace capacity.

Another flight-critical gap is real-time telemetry data. We propose that the drone manufacturer ensures an adequate provision of real-time telemetry information for safe drone flight operations. Examples of telemetry data include battery status, estimated endurance, min/max velocity, min/max vertical speed, altitude ceiling etc. Additionally, U-Space should provide telemetry data of potential conflicts with other traffic, optimal altitude allocation limits and communication signal (GNSS, 4G/5G) coverage area.

The remaining gaps, contingency and emergency flight information can be solved by providing emergency landing procedures via text-based instructions onto the drone user's interface and establish an European Drone Crisis Coordination Cell to apply contingency measures. This will ensure the effective monitoring and communication of contingency measures with respect to impacts from disruptive events.

5) Communication information: Communication information services are some of the fundamental elements for safe drone flight operations, especially in BVLOS urban operations. Conventional manned aviation communication cannot be extended to unmanned aircraft since it relies on controller-pilot data-link and voice communication among air traffic controllers and pilots. A form of direct communication between drone operators/users and UTM controllers can be beneficial by employing cellular network technology, albeit for non-voice communication since it requires higher bandwidth and IP addresses, which could be costly and time consuming for acquisition. Moreover, drones depend on the availability of GNSS for navigation, i.e., the ability to compute its relative position in real-time. The loss or interference to the GNSS availability, compromises the drones mission and it could even constitute to the loss of the drone. Other issues relate to the lack of bandwidth for communication.

Proposed solutions to the above communication information gaps should encompass the provision of a real-time GNSS availability tool such as AUGUR [18], albeit on a hyperlocal scale for drone operators and users. Moreover, cellular network providers should be mandated to provide real-time hyperlocal coverage maps of their respective 4G/5G network availability. Similarly, instant message services for U-Space stakeholders would improve situational awareness, especially for law enforcement authorities. Finally, U-Space should investigate and provide an uninterrupted communication bandwidth for video transfer.

6) Surveillance information: Surveillance information services are critical for drone flight situational awareness as well as manned flight situational awareness. As seen in Table III, the main challenges include the acquisition of state and intent information for real-time tracking purposes, the management of situational awareness information and incident support within the urban airspace. Surveillance information of drones is critical for safe high-density drone operations in an urban airspace. Our analysis indicated a lack of positioning information at the prescribed VLL altitude even for the matured surveillance of manned aviation. This was due to inadequate number of ADS-B receivers and transponders on-board aircraft. In terms of drone surveillance, more reliable surveillance technology is needed.

Proposed solutions to the above drone surveillance information includes installing higher density of ADS-B receivers for capturing position information, mandating all aircraft (commercial and general aviation) to employ ADS-B transponders for position and state information broadcast, governing and managing open-source manned aviation traffic surveillance and Digital NOTAM information and investigating the use of GPS and GSM cellular technology for drone tracking. For drone incident support, U-Space should investigate the use of Eurocontrol's incident support information tool (SASS-C) [19].

7) Drone information: The information pertaining to the characteristics of the drone will assist drone operators in flight and mission planning. Moreover, authorities require the serial number of the drone to be visible on the U-Space system which would create better situational awareness for law enforcement authorities. We accept a bottleneck to develop in terms of providing and managing such information, especially when the system starts to scale with time and technology maturity.

Therefore, we propose a set of solutions to tackle the above issues. U-Space should mandate drone manufacturers to supply all drone performance and specification information directly onto the U-Space platform. This will lower the workload for the drone operator. Finally, U-Space should ensure integrity of drone performance and specification data.

VI. Conclusion

This paper presented the drone information service demands for enabling safe drone operation in VLL airspace with emphasis on the urban environment. A comprehensive review of existing data services from manned aviation and present U-Space/UTM service providers was conducted. The former and latter were compared against the demands from drone operators and users in order to determine the drone information gaps. These requirements were gathered from a survey, a detailed scenario identification analysis and the high-level U-Space principle services. The following conclusions can be drawn:

1) Seven key information gaps were identified: flow management, meteorological, environment, flight, communication, surveillance and drone information.
2) A majority of the existing information services from current aviation cannot be applied for future unmanned operations.
3) Current information services from UTM service providers only assist in providing data services for achieving very low densities of drone flights.
4) Drone information service requirements with regards to flow management contains the most number of challenges that need to be addressed. This is because information gaps such as urban airspace capacity management, and high-density traffic management are critical information services required for achieving safe high-density drone operation in VLL urban airspace.

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