Unmanned Aerial System Operations for Retail

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***Abstract*—The number of Unmanned Aerial System (UAS) applications is quickly increasing as technology, standards and regulation allow them. With each new application, more industrial sectors get affected, and the retail sector is already being impacted. This paper presents five UAS applications that will impact the retail sector: freight, monitoring, guiding, delivery, and advertisement. For each application, concepts of operation are provided along with the associated technological, standard and regulatory locks. These operations are then organized along time, from earliest to latest accessible, with accompanying explanation as to why and when. It is shown that the applications currently most publicized are not the ones that will come first. Finally, a discussion regarding the accuracy of our forecast is proposed and leads to support the enabling of drones, in the retail sector, are provided.**

Keywords–UAS; RPAS; drones; retail; mass distribution; integration; drone operations.

I. Introduction

The retail sector has been quickly evolving in the last decades, as it aptly integrated emerging technologies. The advent of the Internet enabled big data and machine learning approaches, e.g., recommender systems based on customers browsing history to target advertisement [1]; automation changed the way general merchandise stores worked with self-checkout machines and automated drive supermarkets [2]. Smart sensors changed the way online retail stores present their goods, with the development of virtual dressing rooms [3]. Even the most complex technologies have been integrated in the retail sector, with warehouse robots allowing fast and efficient content management [4] and robotic guides improving the customers' experience [5]. The successive technologies transformed the industry in many ways by changing how goods are stored and managed, reducing the number of intermediates, automating dull and dirty tasks, and changing the customers' habits and experience. Now, a new technology is about to become fully available: Unmanned Aerial Systems (UAS). A well-known example is the Amazon prototype [6] for autonomous package delivery. However, there are lesser known applications, which could have more impact on the retail industry and sooner than one might think.

This paper studies five applications in which UAS operations will impact the retail sector. For each application, different concepts of operation are considered. For each operation type, the key enablers are listed. Exemples of such operations, and ongoing research on the topic, are also provided. As the reader may not be familiar with UASs, Section II introduces their architectures, their environment, and their regulation. With this information in mind, Section III presents the five applications along with the technologies and regulation required to enable them. Tentative dates at which these applications will become possible are provided in Section IV. Finally, the conclusion provides future leads to explore in order to enable UAS operations for retail.

II. The UAS world

There are numerous words to designate drones, each with its own meaningful nuance. For the sake of clarity, in the rest of this paper, we use indifferently the terms UAS and drones, with the definitions provided hereafter.

A. UAS Architecture

The S in UAS stands for "System", a UAS is composed of three elements: an Unmanned Aerial Vehicle (UAV), a Command and Control link (C2 link), and a Ground Control Station (GCS). We provide some general information regarding each one of these elements, as it will be useful to understand the limitations in different applications.

1) UAV: The UAV is the aerial part of the UAS. There are numerous ways to categorize UAVs. For clarity we will consider that they can belong to one of three families: rotorcraft, fixed wind, and airship. The most represented type of UAV is the rotorcraft. It does not have wings and entirely relies on the thrust from its propellers to fly. Easy to pilot, especially for take-off and landing, it allows the pilot precise positioning. Its drawback is the energy needed to remain aloft, as well as the noise and wind created by the propulsion. With low endurance, it remains the most popular form of UAV. The fixed wing UAV flies thanks to the lift produced by the flow of air above its wings, like most manned airplanes. For this reason, it must remain inside a given flight envelope and is thus less maneuverable than rotorcrafts. As the lift comes from the air reaction and not purely from the propellers' thrust, it has high endurance and can fly for long periods of time. Plus, it can carry high payload relative to its own weight. It needs an initial speed for takeoff, and some distance for landing, though it is possible to design Vertical Take Off and Landing (VTOL) fixed wing aircraft, greatly simplifying the beginning and end of flight. Its aerodynamic shape allows it to reach high speeds. For a airship type UAV, the majority of its lift comes from a lighter-than-air gas inside its structure allowing it to stay aloft with energy spent only for motion. Consequently, it has the highest endurance of the three types. However, having to store gas onboard gives it a bulky shape which reduces the maximum speed/maneuverability and makes it sensitive to external perturbations (e.g., wind). The UAV also carries the equipage, i.e., the onboard equipment needed for the UAS operation (e.g., flight, rules compliance) but not necessary to perform its assigned task. The equipage comprises the sensors

TABLE I. PERFORMANCES OF DIFFERENT UAV TYPES.

UAV type	Rotorcraft	Fixed-wing	Airship
Endurance	Low	High	Very high
Speed	Medium	High	Low
Manoeuvrability	Very high	Medium	Low
Payload	Medium	High	Low
Cost	Medium	Very low	Low

used to navigate (e.g., GPS, cameras), the communication systems, and the equipment required by regulation (e.g., lights, sound). A brief summary of the differences between these types of aircraft is provided in Table I.

2) C2 link: The C2 link is the medium used to uplink/downlink Command and Control (C2) data to/from the UAV. From an operation point of view, C2 links can belong to one of three categories: direct link, terrestrial network, satellite network. The direct link allows short range (few kilometers) control over a UAV. It has the benefit of not relying on a service provider. For long range operations, the C2 link can be carried over a terrestrial network. Due to the cost of such installations, a service provider is required. The delay in such type of communication is low enough to be comparable to direct link. Similarly, satellite networks allow very long range operations and operations where no ground network is available (e.g., over mountains, water). But it has longer delay than direct or terrestrial networks. This type of C2 link may not be useable for certain types of operations, e.g., indoor operations. Again, due to the cost of such structures, it requires a service provider.

3) Ground Control Station: The GCS can be a simple remote control, a cockpit sized control room, or even bigger. Its size and complexity is related to the type of UAV and the type of operation. However, as the GCS is not considered a limiting factor, we will not take into account the different types of GCS in the rest of this paper.

The capabilities of a UAS change greatly depending on its type and equipage. These need to be adapted to the type of operation to ensure a safe flight while allowing the UAS to perform its mission. Note that, for a same UAS, the regulatory constraints vary depending on the environment and type of operation.

B. UAS Environment

The environment of an aircraft can be classified based on three elements: the available services, the systems required on the aircraft and the applicable procedures. Services encompass all external support to the operation, like aeronautical meteorology or conflicts management. System requirements designate onboard equipment needed to interact with services, other aircraft, and to ensure proper following of procedures. Procedures are pre-defined behaviors that an aircraft needs to follow in certain airspaces or situations. When considering manned aviation, these three elements form the Air Traffic Management (ATM) system; these same elements, when specific to drone operation, form the U-Space system.

1) ATM: The ATM has a strong safety record due to its numerous services, high system requirements and numerous procedures. As a consequence, integrating in such an environment is complex. Plus, the fact that manned aviation is currently flying in these environments asks for drones to be integrated seamlessly, i.e., a drone should be able to behave like a manned aircraft in every aspect. Drones capable of integrating in the ATM system are likely to be large ones, with performances close to these of existing manned aviation.

2) U-Space: The notion of U-Space encompasses the services and procedures offered to drones to allow their integration. The U-Space is planned to be rolled out in four phases: U1, U2, U3, and U4 [7]. Phase U1will bring e-registration, e-identification, geofencing (don't go in this area) and geocaging (don't leave this area). Phase U2 will set up management of drone operations through flight planning, flight approval, tracking, airspace dynamic information, and procedural interfaces with ATM. In Phase U3, operations in dense areas, capacity management, assistance for conflict detection will be rolled out. Finally Phase U4 will provide integrated services with manned aviation, high levels of automation for all services. When reaching U4, all types of operations, even the most complex ones, will be supported by the U-Space services and procedures. U-Space will provide traffic management for small UAS but also drone specific services for large UAS.

Depending on the type of operation, the drones will have to integrate with: neither, one, or both of these environments. However, the complexity of integrating a drone not only comes from the environment but also from the risk of the operation, as will be explained in the next section.

C. UAS Regulation

In order to provide an unified answer to the problem of regulating UASs, national regulators and industries gathered to create the Joint Authority for Rulemaking on Unmanned Systems (JARUS). This entity, building on the European Aviation Safety Agency (EASA) rules, proposed to split UAS operations based on risk levels. The risk is mainly defined in terms of probabilities to hit a human on the ground, another airspace user or a critical infrastructure. This led to the definition of three operations categories (A, B and C) described below.

1) Category A: Category A encompasses low risk operations, like most of leisure flights and some professional activities. Operations falling in this category do not require an explicit authorization from civil aviation authorities. But, they are subject to strict operational limitations (e.g., no proximity to people, traffic, infrastructures; no dangerous items; one pilot per UAS; no item dropping). These operational limitations are sufficient to mitigate the low risk. Though some professional activities fit in this category, the main goal is to regulate leisure types of operations.

2) Category B: Category B regroups medium risk operations, such as operation beyond visual line of sight (i.e., no visual contact between pilot and UAV during flight). To facilitate the regulation process, a set of scenarios with specific operational limitations are designed. To operate within a scenario, the UAS needs to comply with a list of requirements. For operations outside the scope of the scenarios, a risk analysis must be carried out to show that the existing risks are properly mitigated. To facilitate this risk analysis process, JARUS developed a framework called the Specific Operations Risk Assessment (SORA). The SORA considers threats, which contribute to the risk, and barriers, which mitigate the risk, to evaluate the actual risk of an operation and decide if the resulting mitigated risk is low enough to allow the operation. The risk analysis needs to be validated by the authorities in order to authorize an operation not included in the standard scenarios.

3) Category C: Operations with risk that cannot be mitigated in Category B are evaluated in Category C. These represent high risk operations, for example large cargo delivery in urban areas. These are likely to be operations with a risk close to current manned aviation's one. As such, the aircraft, avionics, pilot/crew and operator will need to be certified in order to fly these operations. The fact that a certification process is involved increases the complexity of the introduction of UAS in these types of operations. Indeed, before being able to certify a piece of equipment, a standard must be developed for this equipment. Standardization can be understood as the process of defining details and minimum requirements for safe and uniform operation across a diverse range of implementations. However, as of today, not all the parts required to fly a UAS have corresponding standards, e.g., Detect And Avoid (DAA) systems, C2 links, pilot training. So, enabling this category of operation requires extra effort and time for the industry to agree on standards. For Category C, harmonization at the International Civil Aviation Organization (ICAO) is planned to allow international operations.

4) The special case of indoors operations: Indoor operations are not regulated by civil aviation authorities, so the above categories do not apply. In fact, indoor operations fall under the responsibility of the operator and usually no risk analysis or certification is required by the authorities.

With a knowledge of the existing technologies, environments, and regulations, next section introduces UAS operations that will impact the retail sector in the near to long term.

III. UAS Applications for Retail

In the following, we consider five domains where the UASs will impact the retail industry and examine the prerequisites for integration, as well as the obstacles faced on the technological, standardization and regulatory levels.

A. Freight

Freight operations involve the transportation of large quantities of goods, which represents the input of most retail stores. Depending on the way suppliers operate, opportunities for the retail sector can change. Thus, an evolution of the freight can have an impact on the retail sectors. In the following we analyze two freight operations: cargo flights transporting goods on long distances and cargo delivery to urban areas.

1) LUCA: Large Unmanned Cargo Aircraft (LUCA) offer economic opportunities, as demonstrated by Collins [8], especially when it comes to long haul point to point, delivery to/from remote places and high value cargo over distances requiring multiple piloting crews. Removing the cockpit will cut costs related to having a crew onboard and the associated maintenance. Plus, the UAV will be freed of dynamical constraints related to the presence of humans onboard (e.g., limited acceleration, turning angles, braking force). This kind of operation will ask for integration in the ATM system. Aircraft performing these missions will fly along pre-determined routes, will have to access airport environments, and to follow specific ATM procedures. Because it will fly in the middle of the traffic, this type of operation is classified as high risk, Category C, and will ask for certification. From a technical point of view, transforming large manned aircraft into UAVs is possible with existing technology; the UAV having the same capabilities as existing aircraft, it will integrate seamlessly with the ATM environment. But it will require to agree on some standards. Notably for the C2 link, DAA and Automated Take Off and Landing (ATOL) equipment. Indeed, long range operations ask for a terrestrial or satellite communication network, collision avoidance is a requirement to fly with the rest of the traffic, and operating in airport environments remotely requires ATOL and auto-taxi (from gate to runway) capabilities. The rest of the equipment remains the same so no additional standardization effort is required. Once these hurdles are removed, this type of operation will be at hand. Using LUCA could even open new opportunities. Indeed, in the context of the SESAR2020 projects [9], experiments have been carried out to determine drone specific trajectories which could facilitate their landing on airports without disturbing the existing traffic. It has been determined that UAVs can use steeper descent angles and sharper turning angles. Added to the fact that there is no human onboard, so less airport services are required, this could open access to more options in terms of airports and available supply routes.

2) Urban freight: Urban is currently defined in some civil aviation instances as an area with a density of population higher than 1295 people per square kilometer (plus a 0.5NM buffer around it). Nowadays, delivery of goods to urban outlets is mainly done with trucks. This brings problems related to traffic, and increases the cities' complexity. Using air transport can simplify the way deliveries are carried out. It would still require some urban planning for the landing sites and air routes, but could remove the impact and dependency on road traffic. Moreover, little infrastructure would be required for operations contrary to trucks, which require at least roads, facilitating delivery to peculiar places (e.g., islands, old cities). Comparatively to what can be done today with helicopters, using a UAV would allow saving space and weight by removing the cockpit. Plus, today's helicopters operations over urban areas are mostly exceptional. Developing an appropriate regulation for UAS will allow them to operate routinely. The urban freight operation is complex due to the fact that the UAV is likely to have to go both into integrated airspace (cruise) and low level (take-off and landing), so these UAVs must both integrate with ATM and U-Space. In both cases, flying above urban areas will be classified as a category C operation. A benefit of flying above urban areas is that manned aviation is not allowed near buildings, simplifying operations in terms of DAA for traffic. However, the density of infrastructures requires a DAA for fixed obstacles. Plus, these operations are likely to use stable flight routes, with deconfliction services required considering the operational risk. This asks for U-Space services from phase U3. Due to the size of these UAVs, and to reduce nuisance to the population, it is likely that some areas will be forbidden. Because of the large payloads, delivery from the air or dropping seems unlikely, so the freight UAV will have to land on some properly defined spaces. The limited amount of space will ask for rotorcrafts and/or possibly VTOL UAVs. Urban areas being well covered in terms of communication networks, ground communication will be the preferred solution.

Enabling these operations will take time, as there is no equivalent in manned aviation, so there is little experience.

Having a UAV transition from integrated airspace to low level will ask for equipage to deal with both environments. In integrated airspace, a DAA for traffic will be required, while in urban environment (take-off and landing) a DAA for obstacles will be needed. Developing both of these pieces of equipment for medium sized aircraft is a significant challenge and will ask for research to be done, especially on sensor miniaturization. The sensors will also be crucial for the localization part, as some urban areas can be GPS denied, asking for an independent localization mean. From a procedure point of view, insertion of a relatively slow UAV in the traffic will be challenging. At lower levels, dynamical flight planning will be needed to adapt to a future busy airspace around cities. Procedure for helipad use will also need to be defined, though this could benefit from regulations of cities with high helicopter traffic. A solution to the miniaturization problem can come from the automotive industry. Indeed, hardware and software developed for autonomous cars could answer the requirements for low level flight. The envisioned UAV being on a scale similar to cars, the Size Weight and Power (SWaP) requirements could match. From a procedure perspective, this type of operation will benefit from the advances brought by the current exploratory research projects on U-Space (see current SESAR2020 ERC projects). Alternatively, in the future, a drone could stay aloft and be used as a warehouse while being supplied by ground-to-air freight: Amazons floating warehouse [10].The idea is to have a medium altitude floating warehouse to which a swarm of drones have access. This might serve as a fast delivery platform, assuming the regulatory hurdles behind would be solved in the future. The company patented the design, with details about its fuel efficiency solutions for the route from airship to the delivery destination.

Freight related flights are likely to be among the first high impact operations to be enabled since they already exist and only require modifying the transport medium (from aircraft to UAV). Plus, they don't involve the transportation of humans, greatly reducing the risk. However, operations in urban areas will still ask for complex procedures and systems to be set up before they can take place.

B. Warehouses, Distribution Centers and Outlets Monitoring

Monitoring in those large buildings offers some challenges which can be eased with the help of drones. A wide range of applications can be envisioned like security protocol improvement, customer habits studies, process improvement, and inventorying [11]. Todays solutions can be expensive and lack efficiency. For example, inventory management of distribution centers is most of the time done by human workers via hand-held devices scanning through stocked pallets of goods in labyrinth like aisles. UASs abilities to move quickly and in 3-D will facilitate these tasks with an automated, flexible and cost-efficient solution. Fleets of UAVs going around a building with appropriate sensors can reduce the number of required sensors as well as their cost (closer range, so less costly). The autonomy level required for such tasks is to be able to navigate and avoid collisions with static obstacles and humans (assuming there are no other flying object). Automation will allow the routes to be changed dynamically by the operator providing flexibility and usage of a same fleet for different tasks. The fleet will operate for long periods of times with automated UAV replacement and charging. In this section, we limit ourselves to indoor operations. These applications don't ask for high speed, large payload or maneuverability, the main requirement will be endurance, plus it is indoors operations in a known environment subject to little perturbations. For such tasks, airships are the best pick as they provide high endurance and stability for onboard sensors. The two main tasks of navigation and collision avoidance ask for a precise localization system, which will most likely be based on Simultaneous Localization and Mapping (SLAM) methods which have been extensively studied. Existing sensors, even low-cost ones, like monocular cameras, would allow to perform this task. As there is no interaction with traffic, ATM, or U-Space, regulatory constraints will be low. The two main obstacles for this application are the high level of automation and the operation above the public, which asks for Category B regulatory requirements. Though it will not be the case for all applications, if the UASs operate above the public, they will require mitigation means to prevent any incident developing into injuries on ground. Again, airship provide some de-facto mitigation means because they are lighter than air. For the level of automation, operations with a pilot per UAV, or even one pilot for multiple UAV, does not seem like an economically viable solution. These applications will most likely ask for supervision only from one human who could perform other tasks.

Though not existing yet on the market, all the pieces for these applications are on the shelves. There are no strong regulatory or technological barriers to the introduction of UAS in this context.

C. Improving Customer Experience

According to 2018 retail predictions, the organizations have to review their structure to set the experience of the customers as their priority [12]. With the data based methods, such as machine learning, offering powerful solutions for customer data, it is easy to have a direct link to the habits of individuals which would help to offer preferable solutions to customers. This customer-centric approach would be likely to involve interaction between the customer and the organization both online and in stores, where a drone can be a part of this link. While the concerns of the public about drones is already on the rise before they have started to populate the sky, maybe indoors applications can serve as a warming environment to start with human-machine interactions. A scenario will be to have drone guides that will show you the path to the item of preference, saving time during the supermarket item searches. Their ability to move in 3-D already will allow them to point items in higher shelves where it might not be easy with other solutions. They can even calculate the best route to follow if a list of items is provided. They can offer alternatives for the missing items, shuffling through the database. Another possible application will be drones for assisting with car parking in malls. For big cities, finding a spot in a mall parking might be quite challenging. Multiple drones can work in harmony to guide the customers to the closest parking lot, and win the hearts of the public in time. Yet another application of drones might be to merge with virtual goggles, displaying the stream through a camera on the drone to wander in shops to see the items or environment without the need to actually be there. For example, this would help customers choose the less crowded time to go shopping, naturally improving the customer flow. In this type of application, two operations have to be distinguished: indoors and outdoors. As mentioned earlier, indoors operations are not concerned with civil aviation rules. However, contact with the public asks for risk mitigation measures. To reduce safety concerns, one solution could be to use very small drones (<800g). A rotorcraft or airship of this size would have sufficient autonomy to guide a customer while being small enough not to be a hazard. Since they will be flying in large aisles, avoiding obstacles is not a concern and avoiding the other drones will be the main challenge. Now, for the outdoor case, things get complicated. Mitigation measures to ensure that drones won't crash onto cars will be required. Indeed, a failure to the drone could lead to a car crash. The resulting risk is likely to classify this application in Category C. Moreover, at least U1 U-Space services will be required to ensure tracking and geocaging of the drones in the mall area. In both cases, the fleet management and autonomy aspects will be the main concerns, as they will determine the overall efficiency of the system. Human-machine interaction will also be crucial to allow easy communication between drones and customers. As far as guiding humans with drones is concerned, feasibility studies showed that drones can be used to guide blind runners [13]. Similarly, prototypes of flying street lights have been designed to guide people through cities[14]. Still, guiding simultaneously a group of persons is a challenge yet to be undertaken. For guiding cars, manufacturers like ford are currently exploring the solution for a wider application [15]; guiding cars through a parking could be a first step, yet a challenging one.

When it comes to customer experience, customers are used to have what they need, as they need it, at the time they want, most probably as fast as possible thanks to interactions with computers, internet and mobile networks. Thus, the companies are in a rush to keep up with the race of expectations, otherwise they face to lose the customers quite fast as well. Faster deliveries is of importance and how it might be achieved is described in the following section.

D. Delivery

As mentioned earlier, the advent of internet shopping has profoundly altered the logistics of retail. According to the BBC [16], parcel volumes surged almost 50% globally between 2014-2016 and they are on track to increase at rates of 17-28% annually up to 2021. This has bolstered the need to rethink logistics, particularly in the delivery part. Currently, delivery is mostly done with delivery vans and trucks. Because of the sheer volume of parcels, this is causing problems in big cities. According to [17], in Paris, one moving vehicle in five is a delivery vehicle, generating 25% of urban CO2 emissions. Last mile delivery is also costly: it represents 20% of the cost of the whole delivery chain [18]. This is where drones may come in handy. With their low cost, automation, high speed and flexibility, they could become the future of delivery. This section focuses on the last leg of the journey, more specifically on the last mile delivery, between the warehouse and the customer or a pick-up point. This application can be declined in three operational scenarios: delivery to a remote location, to an urban pickup point, to a house or person in an urban area. Each of these scenarios has its own constraints that will be detailed in the following. For all applications, the main technological capacities needed are endurance, automation, maneuverability, payload carrying ability and DAA. The most important aspect is ensuring the integrity of the data used to automate the flight. If this data is corrupted then the flight might be jeopardized. This means several onboard sensors must be used and fused. Global Navigation Satellite System (GNSS) is to be avoided in the cities (too imprecise). And malicious corruption of the information source must be mitigated. Parcel delivery operations will likely fall within Category B. If parcel delivery falls outside of the set of pre-established specific scenarios, a risk analysis must be carried out and an authorization must be requested. Since delivery drones might be numerous, and certainly will not be the only drones in the urban sky, services from U-Space will need to be at least in phase U2.

1) To a remote location: This is the simplest scenario, flying to a remote location avoiding urban areas greatly reduces the risk to humans. This type of long range mission is best suited to fixed wing or VTOL UAV, with a connection through terrestrial or satellite network. Depending on the remote place to reach, flight can be performed at low levels, taking advantage of U-Space services, or at medium altitude which would require interactions with ATM, thus adding requirements on the operation. Assuming that the flight goes through low density air traffic, because of the remote location, constraints on DAA and deconfliction services are low. However, such long-range operations are likely to ask for a stable flight plan. Thus, a U-Space in phase U2 would be sufficient for this type of operation.

2) To a pickup point: Flying to a pickup point has various benefits. Firstly, the objective is fixed so a stable flight plan can be used. Secondly, a landing facility will be available at the pickup point. However, due to these operations being in urban areas, the landing facility is likely to be small, like a helipad, thus VTOL and rotorcraft will be the preferred UAVs. This type of operation will have to be integrated in the middle of a complex airspace above cities, asking for a U-Space in phase U2 to U3. Protection areas around cities will prevent interactions with manned aviation, so no interaction with ATM would be required in normal operations.

3) To a house/person: This is the most complex case, as each delivery has a different destination which can potentially move (moving person as target), asking for maneuverable aircraft like rotorcraft. From a procedural perspective, this asks for services capable of dynamic flight planning, dynamic geofencing and deconfliction to ensure that the drone is able to reach the person/house. Such a high level of dynamic airspace management asks for a U-Space in phase 4. On top of the equipage required to be integrated in the U-Space, the UAV will need to carry identification means to ensure that the parcel is delivered to the correct customer, increasing the payload. It is still unclear how delivery could be done: dropping the parcel would be dangerous for the customer, and the parcel; attaching it to a rope would jeopardize the flight and be dangerous to the population below; landing for the delivery would expose the drone to hazards like animals, or malicious humans.

As a summary, delivery drones must be agile, enduring, and loaded with sensors; this means that the maximum parcel weight they can carry might be reduced. This also means that the number of drones delivering parcels will be high; and since other drones will be flying for other missions (police, etc.) a high level of airspace management will be required, thus delaying the integration of these operations.

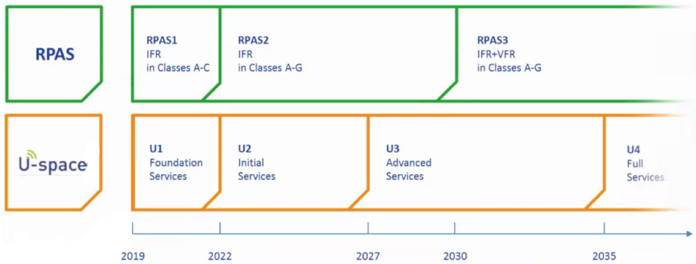

FIGURE 1. THE EUROPEAN UNION TIMELINES FOR INTEGRATION OF DRONES WITH ATM (GREEN), AND WITH U-SPACE (ORANGE).

E. Advertisement

Advertisement has evolved recently with the appearance of dynamic ads and recommender systems. Instead of advertising goods to an as large as possible audience, tailoring advertisement to the customer's needs is now possible. The integration of UASs is an opportunity to develop both approaches. For mass advertisement, UASs could be equipped with banners or signs, depending on their size. For targeted advertisement, displays on a UAV could allow displaying the relevant information to the right customer. For example, one could envision a delivery drone asking for the customer to watch an advertisement (just like on some web videos) before releasing the parcel. This would imply some design challenges. Indeed, UASs are systems optimized for a given operation, with all design factors: Cost, Size, Weight And Power (C-SWAP), being pushed to the limit. Any additional element not directly related to the mission or the UAS might jeopardize the optimality of the design. For example, adding advertisement structures would add significant aerodynamic drag asking for more power or a different structural design. Similarly, adding displays would increase the weight and require more power. This effect can be lessened by new technologies, e.g., by providing more powerful motors, more efficient batteries, better control laws. From a regulatory perspective, privacy concerns might arise from the fact that targeted advertisement in a public place can reveal personal information that a customer would prefer to keep private. This could be solved by technological means (e.g., displaying the advertisement on the customer's cellphone) but it could lead to more customer acceptability issues, on top of the ones linked to the presence of the advertisement itself. This type of operation could be started as soon as drone operations will be allowed in close proximity to humans.

This section presented the operational concepts related to each of the five considered applications, as well as the obstacles preventing their integration and existing projects. The next section compares the different obstacles with the timelines of large European efforts in order to forecast dates at which the required services and procedures will make the operation available.

IV. ENABLING TIMELINE IN EUROPE

Since the beginning, three types of obstacles have been considered for the integration of drones in various types of operations: technological, standardization and regulatory. In the European integration effort, each of these locks is currently tackled by an international effort. Technological locks are being identified and dealt with by SESAR2020, the coordination body for ATM research and development. Lack of standardization is addressed by EUROCAE, the main aeronautical standardisation body in Europe, especially the working group WG-105 dedicated to UAS. In terms of regulation, the EASA is developing a regulation for drone operations.

In terms of obstacles, it appears from the analysis of the previous operations that the biggest obstacles when introducing UAS are likely to be:

- Safety aspects, especially related to the presence of humans near the operation,
- The need to integrate with ATM, or U-Space services, or both,
- High automation levels,
- Definition of standards for UAS sub-systems.

The obstacles and ongoing efforts deployed in Europe are presented side-by-side for each type of operation in Table II.

When the humans are involved in the operation, the risk is lower, and in fact such a scenario is on its way to being regulated in some countries. For this reason, drones for monitoring in non-public places are already at hand. Now when the humans are not part of the operations, like in the customers monitoring and customer assistance operations, mitigation factors are required to ensure a low overall risk level. For both applications, the UAV design and size can be chosen to provide safe operation (e.g., UAV in a ball, micro UAV). For flights far from humans and traffic, the complexity of the operation is related to the amount of interactions with the rest of the traffic. Operating in the middle of a dense traffic is a lot more complex than in less occupied airspaces. For this reason, delivery to remote places will likely come fairly soon. The second obstacle is interactions with the ATM system and manned traffic, though this is a highly complex problem, the fact that it is being actively investigated will enable these operations, like cargo drones, relatively soon. Now, another factor that may delay some operations is the automation level. Indeed, the regulation being developed envisions a pilot for each UAV in Category C operations and possibly one pilot for multiple UAVs for Category B operations. However, to be feasible, some operations will require full autonomy with little or no supervision. We believe this level of acceptance and trust will come only after years of successful drone operations, at which point offering drone services for customer experience outdoors will become a realistic application. Finally, the integration of UAS in high traffic density airspaces, like the future airspace above cities, asks for numerous mitigation measures that large UAV (e.g., freight UAV) will be able to carry, allowing them to operate earlier than smaller ones. Small UAV operations, like parcel delivery, will come with the miniaturization of equipment and setup of UAS traffic management, but that will ask for time.

Based on the SESAR-JU roadmap for integration of drones in ATM and EASA's U-Space roll-out (see Figure 1), considering that EASA regulation is planned for 2019, and in view of EUROCAE's ongoing work, we propose tentative dates for the beginning of each operation. For the EUROCAE timeline, currently studied topics (DAA traffic, C2 link, ATOL) are expected to yield standards in three years (around 2021). Topics not studied yet, if started this year, would still take four to five years to complete. Note that these dates represent the

TABLE II. OPERATION TYPES, MAIN OBSTACLES TO INTEGRATION, CURRENT EFFORTS TO SOLVE THEM, AND TENTATIVE DATES FOR INTEGRATION IN THE EUROPEAN CIVIL AVIATION CONTEXT.

Application	Main obstacles	Main ongoing efforts from civil aviation communities	Prospective beginning date
Freight			
LUCA	ATM integration, C2 link, DAA traffic, ATOL	SESAR2020 projects for RPAS, EUROCAE WG-105 developing standards (DAA, C2link, ATOL).	2022
Urban	ATM integration, U-Space U2 deployment, DAA obstacles, safety (Cat. C)	SESAR2020 projects for RPAS, SESAR2020 projects for U-SPACE, automotive sector developing sensors, existing helicopter procedures.	2027
Monitoring			
Public	High level of automation, public safety	Not regulated by civil aviation authorities.	2018
No public	High level of automation	Not regulated by civil aviation authorities.	2018
Guide			
Indoors	High level of automation, public acceptance	Not regulated by civil aviation authorities.	2018
Outdoors	High level of automation, public acceptance, U-Space U1 deployment, safety (Cat C.)	SESAR2020 projects for U-SPACE, EASA's regulatory framework	2022-2023
Delivery			
to remote location	ATM integration, U-Space U2 deployment, C2 link, DAA traffic, safety (Cat B.)	SESAR2020 projects for RPAS, SESAR2020 projects for U-SPACE, EUROCAE WG-105 developing standards (DAA, C2link).	2022
to pickup point	U-Space U3 deployment, safety (Cat B.)	SESAR2020 projects for U-SPACE, EASA's regulatory framework	2027
to house/person	U-Space U4 deployment, safety (Cat B.)	SESAR2020 projects for U-SPACE, EASA's regulatory framework	2035
Advertisement	Public acceptance	Not regulated by civil aviation authorities.	2018

times at which integration will be possible, however it does not ensure that the industry will develop the applications and that the public will be ready to accept them.

V. CONCLUSION

This paper presented five envisioned applications, with associated operations for UAS, that will impact the retail sector. Each type of operation has been described, and enabling technologies, standards, rules and services have been put forward. This allowed to provide an estimation as to when the different operations will become possible. One must remain careful regarding these estimations as the retail habits are very different from one country to another, and some countries may want to push some applications regardless of the difficulties. The same applies for regulation, with some countries going faster and being more liberal.

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