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INTRODUCTION

In the last hundred years, aviation has advanced at a rapid pace. Commercial and military manned aviation has made unprecedented progress, but development of unmanned aviation is in its infancy. While there are variety of drones available in the market today, practical use of these drones for services such as delivering products is yet to be reality because of missing technological infrastructure, industry guidelines, and regulations to enable and manage drone flights beyond visual line of sight. This paper discusses regulatory barriers on Unmanned Aircraft System (UAS) use, NASA’s UAS Traffic Management (UTM) proposal for Beyond Visual Line of Sight (BVLOS) flights,¹ technological solutions for future safe and secure BVLOS flights, and a design for a distributed drone system that coordinates BVLOS flights between UAS manufacturers, UAS operators, FAA, and UAS service providers to offer affordable UAS services.

I. BACKGROUND

A. Current Drone Technologies and Uses

Today’s drone market offers sophisticated and easy-to-fly drones or UAS for variety of uses. UAS can potentially deliver packages to offices and homes, deliver medications and supplies to people in remote areas and hospitals, perform aerial photography, perform environmental and agricultural analysis, aid in disaster areas, assist in film production, or perform area surveillance. Widespread use of battery-operated UAS to deliver products may also help with traffic congestions and pollution in urban areas. UAS of tomorrow may revolutionize many industries. To make these UAS or drones ready for extensive commercial

services such as package deliveries, regulators must identify risks associated with UAS flights and develop regulations and technological infrastructure to mitigate these risks.

B. Public Perception of Drones

While drone technologies have gained appreciation and recognition across the aviation industry, UAS have yet to gain wide acceptance within communities. A recent United States Postal Service (“USPS”) survey showed that Americans do not trust drone technology because they are worried about drone malfunction, intentional misuse, and drones invading their privacy.\(^2\) Incidents such as a drone crashing near the White House, a drone injuring a triathlete, and a drone nearly crashing into an Airbus A320 have also created skepticism and controversy surrounding drone operations.\(^3\) While drones can assist with surveillance, the misconception that every drone will invade privacy or trespass property is misguided. Pictures and videos taken from cell phone cameras or satellites for Google earth are just as invading as pictures taken from drones. The misconception that drones will crash into planes or kill someone is also misguided. While thousands of people die in road, train, and aviation accidents, there is not a single drone related fatality reported in the United States. Robust technological infrastructure and regulations to manage and maintain drone traffic may change this public perception of drones.

III. REGULATORY BARRIERS

A. Federal Aviation Administration (FAA) Regulations

In the United States, manned aviation follows Visual Flight Rules (VFR) or Instrument Flight Rules (IFR)\(^4\) to maintain safe distances from other aircraft and prevent collisions. FAA

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\(^3\) Conner Forrest, 17 drone disasters that show why the FAA hates drones (June 13, 2018), available at https://www.techrepublic.com/article/12-drone-disasters-that-show-why-the-faa-hates-drones/.

formed Part 107 regulations to guide UAS operations. Part 107 regulates and restricts use of UAS for commercial purposes in many ways. For example, under Part 107, UAS cannot fly at night, UAS must weigh less than 55 pounds, UAS have to fly under 400ft of altitude unless the drone is operated from a building and flies no higher than 400 feet above the structure’s highest point, UAS cannot fly at an airspeed higher than 100 mph, and UAS operators must acquire remote pilot certification before operating UAS. Part 107 allows UAS operators to fly in controlled airspace near airport but requires them to get an authorization from ATC before operating within prohibited airspace near airport through Low Altitude Authorization and Notification Capability (LAANC). LAANC provides real-time processing of airspace authorizations for approved altitudes in the controlled airspace. One the most restrictive portion of part 107 regulation is the requirement of keeping UAS in the operator’s line of sight at all times. This line of sight restriction plays key role in limiting extended commercial use (e.g., UAS package deliveries) of UAS in the United States.

B. NASA’s UAS Traffic Management (UTM) Proposal

Current Part 107 rules provide no guidance for drones flying out of visual line of sight. To make drone services such as “package deliveries” practical it is critical that these drones can fly out of visual line of sight. To accommodate beyond visual line of sight flights, FAA and NASA are working together in developing UAS Traffic Management (UTM). The NASA’s

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6 Id. § 107.29(a).
7 Id. § 107.3.
8 Id. § 107.51.
9 Id.
10 Id. § 107.53.
12 Id.
13 See 14 C.F.R. § 107.31.
14 See Supra note 1.
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Proposal focuses on five core principles in developing UTM to manage VLOS and BVLOS traffic: 1) allow only authenticated operations in the airspace, 2) UAS should avoid each other, 3) UAS should avoid manned aircraft, 4) UAS operators should have complete awareness of all constraints in the airspace, and 5) public safety have priority within the airspace. The guidelines under the UTM proposal are not formal regulatory requirements but are used for test flights in NASA’s UAS pilot program. While these guidelines are adequate for the pilot program, incorporation of them into Part 107 or new regulatory part for BVLOS flights is necessary for practical and widespread use. According to NASA, future BVLOS flights under UTM may operate under a waiver of Part 107 requirements.

Under UTM proposal, commercial drones may fly in uncontrolled airspace out of visual line of sight under expanded LAANC program. NASA and FAA recognize that managing high density UAS traffic along with rest of the air traffic is not easy for Air Traffic Controller (ATC). The UTM proposal also suggests a third party, UAS service provider (USS), to assist drone operators and regulators with managing and regulating drones flying beyond visual line of sight (BVLOS). The NASA’s proposal for UTM requires third-party USS service providers to handle all UAS air-traffic in the airspace. USS providers will assist UAS operators with planning, monitoring, and information sharing with regulatory authority or UTM stakeholders for BVLOS flights. Under the UTM proposal, UAS operators must register UAS, subscribe to a USS service, share operation intent and flight data with USS, and receive authorization from

15 Id.
17 Id.
18 Id.
19 Id.
20 Id.
USS before flying BVLOS flight under Part 107 waiver. As UAS traffic density increases, planning of BVLOS flights, tracking and monitoring these flights, and coordinating the flights with other air traffic is critical. UTM proposal requires USS services to share operation intent of a specific BVLOS UAS flight with other UAS operators to coordinate and prioritize BVLOS UAS flights.

C. Evaluating UTM Proposal

While NASA’s UTM proposal is an important initiative, additional reform in drone regulations and technological infrastructure is needed to make BVLOS drone flights safe, secure and affordable. The following regulatory restrictions and conflicts may hold back widespread use of drone services.

1. Authorization requirement for every BVLOS flight

Under NASA’s UTM proposal, for every BVLOS flight, UAS operator must obtain authorization from USS. Under the proposal, USS will receive UAS facility maps from FAA and authorize UAS operations underneath the ceilings for a map grid provided by FAA. While there are no USS services available in the market today, companies like “Airmap” and “Project Wing” are currently developing them. It is unknown whether these authorization approvals will be time consuming and costly, but this process may affect future BVLOS operations.

2. Drone size

To support cutting edge camera-video technology, sensor technology, flight control, and other advancements, the future drones may be heavier than 55 pounds limit. While FAA and

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21 Id.
22 Id.
23 Id.
24 Id.
NASA should consider allowing drones heavier than 55 pounds, at the same time, they should evaluate inherent safety risk associated with heavier drones. NASA must evaluate the risk that a drone weighing less than 55 pounds poses to public, structures, and other aircrafts verses drones that weigh 1000 pounds. Though drones of larger sizes can be economical, a falling drone of that size would pose a threat to anyone and anything on in its way including human beings, property structures, and other aircrafts.

3. Low-Altitude Airspace Rights

Currently drones can be flown within class G airspace without Air Traffic Control permission.26 Although Part 107 created a federal regulatory framework for drone operations, there is a confusion about what constitutes a legal drone flight under 400ft. In Boggs v. Merideth, the landowner shot down a drone flying 200 ft above his property claiming that the drone was trespassing and invading his privacy.27 The drone pilot asserted he was in navigable airspace under jurisdiction of the federal government.28 While the case acknowledged an issue of federal preemption for lower altitude airspace, the case was dismissed for lack of jurisdiction without addressing the preemption issue.29

The City of Newton in Massachusetts passed a regulation to ban UAS flights below 400 feet, flights over private and public property without the landowner's permission, and required local registration of drones.30 A federal judge in Massachusetts ruled that the City of Newton does not have that authority because it is pre-empted by the federal government.31 The federal

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26 Class G airspace is the lowest level of airspace (below classes A, B, C, D, and E) and currently is considered uncontrolled airspace because Air Traffic Control has no responsibility to direct air traffic in class G. See U.S. DEP’T OF TRANSP., FED. AVIATION ADMIN., PILOT’S HANDBOOK OF AERONAUTICAL KNOWLEDGE 15–23 (2016).
28 Id. at *3.
29 Id.
31 Id.
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district judge reviewing the case stated “[c]ongress has given the FAA the responsibility of regulating the use of airspace for aircraft navigation and to protect individuals and property on the ground and has specifically directed the FAA to integrate drones into the national airspace.”

This specific decision does not impact other states or local laws but other states may consider this decision before passing laws to regulate airspace under 400 feet. If another state government proposes separate airspace regulations for UAS flights, UAS operators may face the challenges of understanding which state law apply to each commercial operation, and whether these laws may be preempted by federal law.

Based on Singer v. City of Newton, though federal preemption regulates the airspace under 400ft, there needs to be firm guidelines and boundaries clarifying whether the federal government, state government, or the property owner owns this airspace. More specifically, the FAA should clarify minimum allowed altitude above properties for legal drone flights.

4. Shared Low-Attitude Airspace

UAS do not just share the airspace with other UAS, but they also share the airspace with manned helicopters, fixed wing recreational and commercial aircraft, military aircrafts, and other types of manned air vehicles. Air Traffic Control must configure the airspace for all types of air vehicles to coexist. Rules for access to airspace must be impartial, clear, and openly available to

32 Id. at 132.
33 See, e.g., Mich. Comp. Laws Ann. § 324.40111(c)(2) (West) (“An individual shall not take game or fish using an unmanned vehicle or unmanned device that uses aerodynamic forces to achieve flight or using an unmanned vehicle or unmanned device that operates on the surface of water or underwater.”); Tenn. Code Ann. § 39-13-903 (West) (“Knowingly uses an unmanned aircraft within or over a designated fireworks discharge site, fireworks display site, or fireworks fallout area during an event… without the consent of the owner or operator of the event.”); N.H. Rev. Stat. Ann. § 207.57 (“No person shall use a drone or UAV with the intent to conduct video surveillance of private citizens who are lawfully hunting, fishing, or trapping without obtaining the written consent of the persons being surveilled prior to conducting the surveillance”); Ind. Code Ann. § 14-22-6-16(c) (West 2018) (“[A] person may not knowingly use an unmanned aerial vehicle . . . to search for, scout, locate, or detect a wild animal to which the hunting season applies as an aid to take the wild animal.”); N.C. Gen. Stat. Ann. § 14-401.24 (West 2018) (“It shall be a Class 1 misdemeanor for any person to fish or to hunt using an unmanned aircraft system.”).
all stakeholders. NASA’s proposal does not provide guidelines on how to manage class G airspace for different UAS operations or missions. For example, UAS in stationary state hovering near ground at low altitude (e.g., to take pictures, to provide surveillance, or responding to emergency) should not interrupt routes of UAS moving at 100mph delivering packages. While current regulations or NASA’s proposal do not suggest specific routes or corridors for different types of UAS missions, separation of slow paced and fast paced drone flights may help making them efficient. For example, if UAS is covering an event, a continuous monitoring of all collision avoidance sensors is required when it is hovering over a large crowd. However, some of these sensors can be disabled if drone is delivering a package and do not expect constant avoidance, which will provide higher speed and processing power to drone delivering a package.

According to the proposal, USS (UAS Service Supplier) should determine routes and authorize flights based on deconfliction schemes. Under this arrangement, one USS provider may plan stationary flight on the altitude where another USS is planning fast moving flight without proper coordination. NASA’s deconfliction scheme requires a UTM Operation to be free of 4-D intersection with all other known UTM Operations prior to departure. NASA’s proposal does not provide details about what platforms and mechanisms USS within UTM should use to coordinate UAS flights to avoid confliction. The proposal, however, specifies that UTM members must use a prioritization scheme for operations, UTM member must have facility to negotiate deconfliction operation with other members, and properly manage intersecting operations. FAA should provide general guidelines about managing airspace under 400 feet according to the required speed for the mission rather than rely on USS. In absence of FAA

34 See Supra note 16.
36 Id.
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guidelines, different USS providers would have to agree on dividing airspace for fast paced and slow paced UAS operations.

5. Requirement of licensed pilot to fly UAS

Under NASA’s UTM proposal, only a Part 107 licensed pilot can fly both commercial VLOS and BVLOS UAS flights. 37 For a commercial IFR flight, FAA permits pilots to use a certified autopilot and flight controls to autonomously fly the flight plan and control the aircraft. 38 UAS Autopilots and flight controls on the market today also provide options to draw waypoints and autonomously control the UAS flight. 39 NASA’s UTM proposal does not address the idea of completely autonomous BVLOS flights using an autopilot and flight control. For an affordable and extended drone delivery service, regulators must waive licensed human pilot requirement when a sophisticated autopilot can fly UAS autonomously with same accuracy and precision as human pilot. While Part 107 do not specifically allow a completely autonomous UAS flight, the rules do not restrict the possibility of an autonomous UAS flight. In enacting Part 107 regulations, FAA has stated that autonomous flight of small unmanned aircrafts (UAS) will be allowed under this rule. 40 FAA has further recognized that “the ability for a small unmanned aircraft to fly autonomously could add significant utility to a small UAS…operation and would further encourage innovation in the industry.” 41 The FAA has also clarified that a remote licensed pilot is required to monitor and able to take full control of an autonomous flight. 42 According to FAA, there is insufficient data to establish whether small UAS will yield

37 Id.
41 Id.
42 Id.
the right of way to another user of National Airspace that may enter the area of operation without human input. The FAA appears to agree that human pilots should not have to fly every drone flight when an autopilot and flight controls can safely perform drone operations, but the Part 107 regulation do not properly reflect their view.

V. TECHNOLOGICAL BARRIERS

A. Self-Piloting Drones

Requiring a human to fly every drone flight raises concern about the economic feasibility of drone services. An Autopilot with flight control as a complete system can enables UAS to autonomously fly waypoints while keeping aircraft stable. Many available UAS in the market already provide autonomous navigation with reference to external commands such as taking pictures, videos, or performing agricultural operations. A drone equipped with an autonomous navigation may perform certain activities (e.g., taking pictures) better than human pilot because holding altitude stable for longer periods and perform certain maneuvers may not be easy for a human pilot. Future self-piloting drones must be capable of autonomously adapting assigned drone routes and controlling the UAS to follow the complete assigned routes. NASA’s UTM architecture requires a licensed pilot to fly UAS, where USS (UAS service supplier) may provide route, weather, and airspace constrain information to the pilot. As discussed, current NASA/FAA UTM proposal does not allow an autopilot or flight control flying complete BVLOS flight without assistance from human pilot. UAS equipped with flight control board and basic sensors such as accelerometer, gyroscope, compass, barometer, GPS, and airspeed sensor may provide autopilot functions and control a complete drone flight. These sensors help calculate

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43 Id.
44 See Supra note 39.
45 See Supra note 16.
46 Id.
current altitude and angle the drone is flying, direction the drone is facing, change in air pressure, measuring airspeed, measures your drone’s location, and would allow the flight control to perform necessary corrections for stable flight to waypoints. Open source autopilots such as Ardupilot and Visionair have tried to integrate a flight control board into the UAS that reads sensor data and calculate commands to self-pilot the flight. Yet universally trusted and FAA certified autopilot or self-piloting drones do not exist in the market today. As discussed, FAA has agreed to an autonomous navigation of UAS as long as a remote licensed pilot is monitoring and able to take full control of the flight. FAA and NASA may reanalyze this prerequisite once sophisticated UAS with robust autopilot systems are available that can safely fly complete autonomous flight.

B. Robust Flight Management System

As UAS traffic density increases, UAS designated airspace may become disordered if not properly managed. For every Beyond Visual Line of Sight (BVLOS) flight, ATC providing guidance about where to fly to every operator is probably not a feasible option considering that one million drones have already been registered in the FAA registry. NASA suggests that USS providers or separate flight management service providers should provide route options that maximizes drone services efficiency to meet their business goal. In NASA’s UTM initiative, ATC will provide flight constraints (e.g., conditions in airspace, nearby traffic, etc) to USS for

50 Id.
52 See Supra note 9.
them to plan, schedule, and manage BVLOS operations. USS that participate in UTM may use this information as input to plan routes and to keep separation between two drone flights. Coordinating standard routing strategies between USS providers or flight management service providers to improve flight planning and in-flight situation awareness will be essential to keep the airspace ordered. Flight planning will also have to consider type of flight missions before assigning routes to UAS flights. Agricultural or infrastructure inspection missions involve low-altitude flights back and forth over a plot of land to measure soil or plant conditions. The Flight management system would also have to consider specific regulations and restrictions before assigning specific route for a drone operation. The routing strategies may have tradeoff between freedom of flight and amount of ordering it provides to the airspace. USS may provide a flight management system (FMS) where a UAS operator may enter origin and destination for a drone operation, operation intent, and special instructions, and USS FMS automatically generates route for UAS operators while informing other USS services about the authorized route and operation intent. In alternative, the USS may give users an option to create their own flight plan for BVLOS flight as long as the route is communicated with USS in order for USS to manage and control BVLOS flights without any conflicts.

Drone flights performing missions in high density airspace may use fixed routes, corridors, or other strategies to avoid conflicts and obstacles. A delivery warehouse, for example, has many drones approaching and departing, requiring coordination to operate safely. Flight management systems can organize safe routes between buildings in an urban setting, with special navigation aids to ensure high-precision guidance in complex environment. Fixed flight routes can ensure safety when there is high traffic density or in any location where structure is

\[ Id. \]
needed to ensure safe operations. Flight planning also needs to adopt emergency requests when commercial and military aircrafts require access to fly through UAS dense airspace. Some of the drone services offer drone operators to set multiple GPS points, or waypoints, and enable the drone to automatically fly to them but ATC or USS are not aware of the drone flight plan.\(^{54}\) If a specific USS or drone services help drone operators to create routes for BVLOS flights, USS must communicate and coordinate their routes and arrangement other USS service providers. So, other UAS operators can avoid creating flight plan that would interrupt another drone’s flight path.

By 2022, according to FAA, the number of registered drones will go higher than 3.8 million.\(^{55}\) As drone density increases in the airspace, risk of collision and drone accident will also increase respectively. Geofencing technology, software that creates a virtual wall around restricted or prohibited airspace for UAS flights, avoids UAS from flying into restricted airspace, but Relying on Geofencing applications for airspace restriction may not be enough in emergency. Geofencing may not be up to date on recent airspace restriction or someone may have geofencing disabled on a drone. For this, USS may need to provide access to regulators (FAA) to take control of the drone that is flying in prohibited airspace and bring it down in a controlled manner. One study showed that helicopter windscreens could be critically damaged by collisions with a drone in several realistic scenarios.\(^{56}\) With respect to smaller unmanned aircraft (UAS) flying at lower altitudes, collision with human or individual properties is also a safety concern. This means services like registration, tracking, control transfer, identify management, auto-pilot,


etc must provide quickly risk assessments and emergency alerts. Emergency protocols must exist for emergency to access the airspace and accident site to ensure safe and secure traffic management of drones. Under UTM proposal, NASA has emphasized that there must be a prioritization scheme for operations within UTM that is facilitated via USS. The strategic deconfliction scheme must be well-documented for the understanding of operators and supported by all USSs. As specified in NASA’s guidelines, the prioritization scheme must allow for preemption of operations with lower priority by those with higher priority, deterministically calculable by each USS given the same operation data, a function of operator, operation, airspace, and vehicle parameters.

From the NASA’s perspective, strategic deconfliction is a key player in the conflict management model for UTM and a core service that will operated by all USS participants in the future UTM System. The conflict management model will need to collaborate with flight management system and autopilot to determine flight route and compute waypoints according to the prioritization and negotiation scheme.

C. Dynamic Geofencing

Under NASA’s UTM proposal, regulators will notify USS providers about restrictions on airspace use, such as no-fly zones based on aircraft risk or capability, or air traffic management decisions such as routing changes. In response, USS may restrict UAS operators from flying in restricted areas using dynamic geofencing technology. Geofence is a virtual wall around restricted or prohibited airspace for UAS flights. Geofencing is like a fence around your home

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57 See Supra note 35.
58 Id.
59 Id.
60 See Supra note 9.
and if someone enters the yard, an alarm is triggered.\footnote{Id.} Similarly, geofencing can ‘fence off’ a drone entering in a sensitive or restricted area using a virtual perimeter programmed with GPS location data that keeps drones from veering into restricted air space.\footnote{Drew Dixon, \textit{Geofencing Stops Drones in Their Tracks} (Aug. 1, 2017), \url{http://www.govtech.com/public-safety/Geofencing-Stops-Drones-in-Their-Tracks.html}.}

The geofencing capability enables USS providers to automatically restrict drones from flying into no-fly zones in real time with dynamic restriction updates. Geofencing applications such as DJI’s GEO, Yuneec, GoPro provides information airspace restrictions for UAS flights.\footnote{John Patterson, \textit{Heliguy’s Guide to Geofencing} (Feb. 16, 2017), \url{https://www.heliguy.com/blog/2017/02/16/heliguys-guide-to-geofencing/}.} Some of these applications also automatically restrict the UAS from entering restricted airspace.\footnote{Id.} Oftentimes, regulators may have to close the airspace temporarily. For example, during wildfires firefighters use helicopters to combat the fire and drones in these areas may interrupt their operation and cause unnecessary damages. Dynamic geofencing integrated with flight management systems should spontaneously create an alternative route for UAS in real-time or provide notification to operators to leave the territory immediately.

To implement robust geofencing, it is also imperative that FAA or ATC inform about TFRs (Temporary flight restrictions) in an airspace structure in the shared environment where all USS providers can have real-time access to them to take appropriate action using active and passive geofencing. At the same time, USS providers must continually monitor and update topography to enable robust geofencing system that is easily accessible to drone operators, flight management systems, and autopilots create and amend the BVLOS flight plans according to the airspace restrictions.
D. UAS Tracking and Monitoring

Safety is one of the top priorities of drone flight and being able to monitor drone flying beyond visual line of sight is critical. For VFR and IFR flights, ATC uses mechanisms such as Automatic Dependent Surveillance-Broadcast (ADS-B) to monitor and track aircrafts.\textsuperscript{66} Similarly, USS or regulators may monitor UAS flights if UAS broadcasts identification and position information using ADS-B. In the NASA’s BVLOS flight option, it requires USS to constantly track the drone flight and monitor its position to ensure that the UAS conforms to the shared operation intent.\textsuperscript{67} But the NASA’s proposal does not specify a standard or protocol for tracking and monitoring UAS flights. While there are number of options to transmit data from drone to USS or ATC, the transmission must be secure and reliable transmission. USS may choose to communicate with UAS with existing UAS communications channel such as legacy command and control (C2) links. Command and control (C2) link is a data link between the remotely piloted UAS and the remote pilot station for the purposes of managing and controlling the flight.\textsuperscript{68} Because this C2 link enables UAS operator to fly UAS by remote control, the C2 link is readily available for tracking UAS. There are several trusted C2 link solutions available for mission critical applications by the government and defense industries.\textsuperscript{69} With the appropriate security measures and data encryption capabilities in place, C2 links are better protected to thwart malicious attacks on UAV systems.\textsuperscript{70}

\textsuperscript{66} Airspace (April 16, 2018), available at https://www.faa.gov/nextgen/equipadsb/research/airspace/.
\textsuperscript{67} See Supra note 9.
\textsuperscript{70} Id.
While C2 link is a strong candidate for identifying and tracking UAS, the transmission range for C2 link may vary based on size and capability of drone. Broadcasting built in drone ID via C2 link requires no costs for UAS owner or operator to enable regulators to track and detect UAS. With C2 link, a drone operator also can’t disconnect C2 link to misuse UAS because otherwise the operator would not be able to fly it. Manufacturers of UAS need to ensure the C2 links are provided not only by reputable wireless communication providers, but those with a proven track record of successful implementations in the field. This is because C2 data communication links with advanced encryption capabilities can help thwart hijacking attempts, signal interference issues and unauthorized access to critical data, all while ensuring dependable data transmission. These standards are tried and true and by incorporating these techniques into the C2 data communication link for unmanned systems, we can ensure the reliability necessary for introducing these platforms into the national airspace. With a secure C2 link in place, UAS are far less likely to suffer from technical errors. This is a key consideration because not only will there be more aircrafts operating in commercial airspace, but many will transport critical information where failure to operate is not an option.

Drones equipped with ADS-B can also help with tracking and collision avoidance as everyone with ADS-B receiver can see drones broadcasting using ADS-B. ADS-B is an internationally standardized aviation technology mandatorily being installed in airplanes and helicopters worldwide. The ADS-B integrated in UAS will announces its own identification, position, altitude, and direction for anyone with receiver to hear. ADS-B may not be the ultimate solution because if ADS-B receiver were to show all the drones along with other air traffic,

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71 Id.
72 Id.
ADS-B receivers in cockpit or at ATC may display too much information which may be hard to interpret.\textsuperscript{73}

If C2 link is the UAS communication solution, establishing a flexible and interoperable C2 system will become much harder without technical standards. Under UTM proposal, NASA has not provided standard communication protocol for C2 system for BVLOS flights. Lack of UAS C2 technical interoperability standards (at the appropriate protocol layers) presents a serious impediment to the widespread and harmonious implementation of UAS C2 systems and associated assignment and tracking processes.\textsuperscript{74} Apart from determining C2 link standard, it is important regulators figure out what are right things to share while protecting privacy information. NASA’s proposal does not specify what UAS information (e.g., identity, route, intent, and other aircraft data) BVLOS flights will have to share with USS or other stakeholders. Making sure there is right balance to ensure safety and secure operation without publishing business specific information that can harm the business or jeopardize privacy.

Along with using C2 links for tracking and monitoring the UAS, USS may allow to gain control over UAS using C2 links in emergency. To avoid a drone accident, it is imperative that USS or regulators have an access control method to gain control over UAS flying BVLOS flights. The goal of access control is to allow network access by authorized devices and to disallow access to all others. Access should be authorized and provided only to devices whose identity has been established (authenticated) and whose placement on the network is approved in accordance with network plans, designs, or policy. In general, because communications mechanisms have critical role in tracking and monitoring UAS, defining a standard that whole

\textsuperscript{73} Christian Ramse, The Battle For Drone Tracking Technology, uAvionix (May 1, 2017), https://uavionix.com/blog/the-battle-for-drone-tracking-technology/.
\textsuperscript{74} Denise S. Ponchak et. al., A Summary of Two Recent UAS Command and Control (C2) Communications Feasibility Studies, NASA.GOV (2015), https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20160009136.pdf.
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drone industry will adopt is important and essential for BVLOS flights. Determining this standard for communication should be at top priority, to allow UAS manufacturers, USS, ATC, and UAS operators to integrate this technology and enable UAS for BVLOS flights.

E. UAS Registration and Identification

Drones need to have unique identity separate from operator just like plate number of cars. Currently identifying a UAS in the sky is nearly impossible and even harder to identify the operator. The industry needs a reliable, globally harmonized standard for identifying a UAS e.g., authoritative registry for positive ID and tracking of UAS. Currently UAS operators must register drones with FAA if they are flying drones for commercial purposes.\textsuperscript{75} The FAA registry basically contains drone registration along with drone operator’s email address, credit, or debit card, and physical address.\textsuperscript{76} That said, FAA is not able to use this registration information to identify drones in the sky or monitor the drone. There needs a national authoritative drone registry to provide efficient drone registration system that allows regulators to identify using digital drone identification and monitor drone throughout lifecycle of the drone. The drone identity standard would also have to meet the exponential growth of UAS, provide high level of privacy protection for UAS operators, uses existing technologies to minimize cost and development time, and maintained using third party such as USS.

A digital key generated online using SSL/TLS certifications are usually secure communications on the internet. SSL/TLS certificates grant permission to use encrypted communication via Public Key Infrastructure (PKI) and authenticates the identity of the certificate holder.\textsuperscript{77} UAS operator or supplier may use SSL/TLS certificate to register drone and

\textsuperscript{75} See Supra Note 21.
\textsuperscript{76} Id.
to further communicate with ATC and USS providers. Drones may broadcast a digitally signed identifying number, location, and timestamp to those on the ground using communication technology such as LTE while ATC or USS on ground can authenticate the drone using PKI. PKI certificates help ensure that a drone’s identity can be trusted and has not been spoofed or hacked. These type of digital certificates leverages existing infrastructure capabilities and technologies without requiring hardware change in drones while allowing for industry wide adoption and standardization, minimizes impact on OEM.

SSL/TLS certifications may provide reliable, scalable, and a globally harmonized standard for assigning of a unique identifier and authenticating UAS. For a BVLOS flights, a drone owner may follow the below steps to get their drone registered after purchasing from drone manufactures. First, the drone owner would register the drone online with serial number and owner identifying data. Second, USS or FAA may issue a unique drone identification (public key) for the user. Third, drone registry would require an update to include drone unique identifier and operator data associated with the drone. Fourth, the unique drone identifier provides regulators and other stakeholders to positively ID UAS and identify owner/operator.

Under NASA’s UTM initiatives, Intel is working with NASA and FAA to create open standard called “Open Drone ID” that will help solve the remote identification and tracking of unmanned aerial systems (UAS).\textsuperscript{78} NASA and Intel suggests this standard is a beacon-based (wireless drone identification) solution that enables drones to be identified when within range of a receiver, like a smartphone.\textsuperscript{79} Intel suggests that the standard may use Bluetooth to broadcast packages to broadcast unique drone identification, location, direction, altitude, speed,

\textsuperscript{79} Id.
make/model, base location, and other related data. Further detail about this standard is currently unavailable but it is important that “Open Drone ID” is a global standard provide broad scalability to large number of drone operators, USS providers, and ATC. The standard must also support different use cases when strong network is not available or suggest substitute means for communication. Because details about this standard is currently unavailable, it is unclear how this broadcast mechanism will integrate with current mechanisms such as radio frequencies, ADS-B to create unified Air Traffic Management (ATM).

F. UAS Obstacle Avoidance Mechanism

For a drone or a self-driving car to detect objects and then act to avoid the obstacle by determining whether to stop, go around or above the object involves many complex technologies working together to create such collision avoidance system. Various drones in the market today are using obstacle avoidance sensors such as stereo vision, time-of-flights, lidar, infrared, monocular vision to avoid collision with other drones or objects. Drones for different missions may have different collision avoidance sensors. For example, The DJI Spark obstacle avoidance system works well when using it in a crowded area but an operator may turn off the avoidance system if drone is flying in less crowded open field to fly the drone with higher speed. NASA and FAA should recognize that different UAS missions may require such collision avoidance sensors to be enabled or disabled for safe and efficient UAS flights. More specifically, FAA and NASA should establish industry standards for UAVs with specific intent requiring a specific obstacle avoidance system.

80 Id.
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IV. DISTRIBUTED DRONE SHARING SERVICES

A. Design for a Drone Sharing Service

Apart from regulatory and technological barriers, affordability is also a hurdle to extended use of UAS for commercial purposes. An individual may desire to use a drone service but simply cannot afford the drone. Moreover, many potential drone users do not have license to fly the drone. A distributed drone system that coordinates BVLOS flights between UAS manufacturers, UAS operators, FAA, and UAS service providers, and still offers affordable UAS services to consumers will be desirable once the NASA’s proposed UTM infrastructure is well-developed.

The following design for a distributed drone system allows drone owners to provide available drones to potential customers who can request a drone service using a mobile or web application. In an example use case, a user wants to check his future house construction progress without having to drive to future home. The user may not know how to fly a drone or own a drone. The drone sharing service would allow a user to request a drone service with specific directions, perform the service for the user (e.g., go to user’s home and take pictures), and provide pictures of the house to the user online. In this case, user would neither have to buy a drone or learn how to fly a drone but simply pay for a drone service. The proposed drone sharing system takes out the complexity involving drone operations by offering a drone as a service and regrouping various stakeholders in marketplace.
B. Architecture for a Drone Sharing Service

As shown in the Fig. 1, the distributed drone system will allow UAS owners to share their UAS for drone services, customers to request drone services, and perform the requested drone operations with assistance from USS service providers, UAS pilot, charging services, inspection services, and other service suppliers. The drone sharing system will enable drone owners or manufacturers to make their FAA registered drone available for service. On the customer interface front, the drone sharing system may enable customers to choose from available services (e.g., deliver packages, area surveillance, etc.). The system may automatically choose appropriate drone for the service or provide options where customers can choose a specific drone to perform a service. The system forwards the request to UAS service supplier (USS) to verify registered drone with FAA, authorize BVLOS Flight according to FAA flight restrictions, assign flight plan according to traffic, weather, airspace restriction, and deconfliction scheme. USS may use third party service for any of these tasks. For example, USS may use third party
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weather service or geofencing software to determine route for the drone operation. The system requests a licensed drone operator to fly the route and perform the service. While drone operator is performing the service, USS may monitor the flight and dynamically update route or inform pilot if an emergency. USS may also shares UAS monitoring with the drone sharing system for a customer to track drone service in real time. Once UAS operation is completed, USS notifies the system and the system notifies the customers, checks whether drone requires recharging or any repair work. Once the UAS is ready for next operation, the system lists the UAS as available for operation in the UAS database.

The distributed drone system involving many entities (e.g., drone supplier, customer, USS (and services used by USS), charging service, ATC, maintenance service, etc) can be developed using traditional centralized databases, network protocols, and algorithms. Blockchain technology can also help implement such system where smart contracts mechanism integrated with Artificial Intelligent algorithms can create decentralized asset (e.g., UAS) tracking network for secure and safe operations between all entities. Since there will be lot of intermediaries between when a customer requests a drone service and a drone operator completes the service, the main questions arises is how all these intermediaries can trust each other to have done their jobs. For example, if a drone is sent to maintenance service, the maintenance may claim they didn't receive it on time and delay drone services. Smart-contracts make these transactions between multiple entities highly transparent. The involved entities can't just claim they didn't receive something on time or they meant to complete service on this time/day instead of a different time because every transaction is visible on the Blockchain network.

Smart contracts also enable small drone manufacturers to enter into the system of drone sharing. Trust is a big issue when allowing an individual or small company to make their drones
available for various services because they do not have a reputation. Blockchain smart contract can assure that only trusted drones are allowed in the respective airspace. Implementing drone subscription system using distributed technology such as blockchain, efficient AI based algorithm and secure communication protocols will help building robust and secure shared drone system.

MOVING FORWARD

To make safe and secure drone operations using a UAS sharing and subscription system to large population may not be possible in immediate future but NASA’s UTM initiatives and research promises a bright future for UAS flights. For BVLOS flights, regulators may want overly conservative restrictions and constant monitoring while drone operators may prefer relaxed regulations. The regulators should not impose restrictive regulations in fear but instead should evaluate risks of drone flights based on population, structures, and air traffic density, and impose regulations according. The regulators may consider relaxing regulations for drone operations in sparsely populated locations or drones with lighter weight. Along with regulations, FAA, and NASA must provide guidelines and standards for drone identification, communications protocols, concrete confliction schemes, airspace constraints, collision avoidance sensors, and emergency procedures to UAS service suppliers and UAS operators. Regulators should also take keen interest in certifying and approving flight management system, autopilot, geofencing, and flight control systems that make drone flights autonomous, affordable, safe and secure. Once regulators finalize regulations, provide procedure and guidelines, determine standards, and certify recommended UAS flight systems, UAS service provides can start following these guidelines and kickstart BVLOS drone flights across the United States.