Obstacles to Deployment of Civilian Unmanned Aerial Systems in the U.S. National Airspace

in Disaster Situations

A White Paper

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SCOPE

This paper will outline and identify many potential obstacles unmanned aircraft operators can expect to encounter during a deployment under the auspices of first responders in a disaster situation. Because of the complexities of each of these issues, it is assumed that the reader is familiar with unmanned aircraft operation, and is a seasoned, tenured first responder, familiar with disaster mitigation efforts in general. It should also be noted that many of the issues reported in this document are dynamic and change rapidly based upon need, economy, and law and should be reviewed and updated frequently to keep abreast of developments in the unmanned aircraft industry. This White Paper is specific to "civilian" UAS or UAV (unmanned aerial system or vehicle); those not designed for "dual use" or defense technology purposes, or requiring military/security clearances for use.

INTRODUCTION

The most common obstacles to insertion and use of unmanned aerial systems (UAS) into disaster situations in the national airspace (NAS) are varied and many. Disaster situations, for the purpose of this report, include natural disasters (fire, flood, weather driven emergencies, earthquakes, etc.) and man-made disasters (chemical or other agent spills, transit disasters, infrastructure failure, domestic terrorism, etc.) To clarify, UAS have many monikers, i.e., unmanned aircraft (UA), unmanned aerial vehicles (UAV), remotely piloted aerial systems (RPAS), or "drones" as commonly referenced by the general public.

Background

The military use of UA introduced the drone technology to the general public. Over the last decade, in many instances, the typical image displayed for any story or report concerning these aircraft was typically the large, high-altitude flying, Predator B ™, complete with missiles necessary for battleground effectiveness. More recently, civilian UAS have seemingly burst onto the scene frequently over every park and stadium, along city streets and neighborhood yards. While in fact, UA have been in use for years for various types of civil service in the NAS. For example, unmanned aircraft have flown into hurricanes and provided data for the study of flooding and coastal erosion by NOAA[1]. Over the past decade, a number of university systems have also turned to drone technology to gather important research data.

Most small, civilian UA design grew from innovative individuals and businesses from the model aircraft and hobbyist fields. Thus, in the early days the UA were considered "model aircraft" by the federal government and its agencies, in particular the Federal Aviation Administration

[1] http://uas.noaa.gov/news/

(FAA). As a result, the development of small, civilian unmanned aircraft was being done by small businesses and in garage shops, truly "below the radar" and with little attention from the public at large or the media. The last five years of innovation has demonstrated a quantum leap in the technology and the resourcefulness of private citizens to exploit the limitless uses of the UA. While sales of the civilian UA have exploded on the market, safe and measured use of the UA by the general public has not evolved concurrently. Nor has a comprehensive approach for use of UA in disaster situations. Missing is a critical, strategic analysis and policy that identifies safe, structured approaches for UA use in the NAS, by law enforcement, fire, and other emergency response teams.

As UA began to be utilized in the private sector for commercial and scientific purposes, their incursion into airspace occupied by full-scale, manned aircraft has become a flashpoint of differing industries and philosophy. At the same time, the lines were blurring between "model aircraft" and the more sophisticated civilian UA, with useful technology and sensors on board, which came to be known collectively as "drones."

As the civilian UA technology advanced, driven in large part by the private sector, lawmakers and regulatory agencies have responded to control the proliferation of these UA in the NAS. One reason for this reactive response is the major news stories concerning UA use in combat. These reports typically do not identify an intelligent delineation, by the media or agency reporting, between combat vs. civilian UA, leaving many U.S. citizens fearful of any drone flown over our homeland. Thus, UA often times are considered as an "intrusive technology" threatening privacy and safety of U.S. citizens. The reactionary efforts for control by the U.S. regulatory agencies and lawmakers have been implemented, in many cases, in a broad brush manner without a comprehensive scientific methodology to differentiate any benefit vs. risk analysis during use of civilian drones.

Along with the identification of obstacles, some suggestions may be offered in each of the sections of this report. There are technology considerations that cannot be predicted but hypotheses exist based on current developments and will be mentioned where applicable.

As this technology advances and becomes more commonly utilized, it is imperative that the UA industry's unmanned aircraft operators take a stance similar to those in the medical profession i.e., "first and foremost, do no harm." If this simple credo is adhered to, wise, safe decisions will follow in the deployment of unmanned aircraft in all environments.

MANNED AIRCRAFT BIAS

Currently, the use of aircraft in a disaster situation is generally the sole purview of the full scale manned helicopter (rotor wing) or fixed wing aircraft. The use of unmanned aircraft in a disaster situation is a challenge to the paradigm established over decades by successful manned aviation. To some manned aircraft pilots, the technological advance and use of UA has become a divisive issue between the two broad aviation categories, and airspace is defended passionately. Disparate groups have joined together to argue for new restrictions and eventually, the enactment of federal laws, to prohibit the use of UA in the NAS, for a variety of reasons from privacy, to safety, to economic calamity. Groups such as the Air Line Pilots Association (ALPA) and the Aircraft Owner and Pilots Association (AOPA) have used the force of membership numbers and dues to appeal to lawmakers for further restrictions. These associations had earlier called for the immediate banning of all aircraft that could not demonstrate the "equivalent level of safety" of manned aircraft.

To an extent, these are real concerns for today's manned aircraft pilots. Intrusion by UA into the NAS has been documented in and around airports, in Class B airspace and other occupied airspace. Irresponsible and/or ignorant UA operators' or hobbyists' disregard of regulated airspace is potentially dangerous. It becomes imperative to identify potential dangers and educate, not only the UA pilot, but the manned aircraft pilot on safe, coordinated UA operating procedures during times of disaster. The number of UA deployed to reconnoiter and gather data following a disaster can exponentially decrease response time and make better use of manned aircraft to devastated areas and the unfortunate people in them. Currently, the civilian UA technology is focused on the smaller sized UA – under 55lbs. However, large, full scale aircraft piloted only by the computer(s) on board or instructions from afar by a skilled human pilot is coming in the not so distant future.

The Federal Aviation Administration is the regulatory agency responsible for the safety of the National Airspace. Understandably, this agency is populated by pilots, commercial aviation industry professionals, and general aviation aircraft operators. The introduction of the Federal Aviation Regulations, or FARs, was to protect and promote the safety and education of a then, budding commercial aviation industry. Anything other than a kite or a balloon that did not have the capability of carrying a person was considered a "model aircraft" and did not require FAA attention. The only recognition of "model aircraft" by the agency was under an Advisory Circular, AC 91-57, which consisted of four short paragraphs that directed "model aircraft" operations away from manned flights near airports and below 400 feet above ground level (AGL). The model aircraft community continued to thrive under AC 91-57 for 50 years and a community based safety standard was developed by the Academy of Model Aeronautics (AMA).

The most recent clarification of Part 91 by the FAA did as much to show this manned bias as it did to level the legal playing field by refining the definition of "aircraft." Aircraft are now defined as "ANY contrivance designed to fly through the air" and the recent clarification goes so far as to address mundane items such as a Frisbee or even a paper airplane as an aircraft under the umbrella of the FARs. This blanket declaration immediately brought to focus the ambiguity of applying regulations to aircraft that were clearly unable to comply.

Regulation of any intrusive technology having a heavy monetary impact on industry or society typically starts off as highly restrictive. Such is the case with UAS. Regulation modification occurs as the technology gains acceptance – simply, the benefits of the technology and passage of time expunge the fear. For instance, the first automobiles were required by law to pull over and stop their engines so as not to frighten passing horses pulling wagons or carriages.

Acceptance of the UA technology in the new millennium is predicated as much by its use in the military as it is in industry. The armed forces have used remotely piloted aircraft for decades with early examples documented shortly after World War II. Recently, the Air Force in particular has indicated that their fighter aircraft will be pilotless by as early as 2020. This is evidenced by the conversion of retired F-16 and F-18 aircraft to pilotless status to be used in the role of drones to train combat pilots with a technological twist. These drones can use sensors to respond to their attacker and effectively evade and re-engage, reversing the hunter-hunted roles.

PUBLIC PERCEPTION OF UNMMANED AIRCRAFT

The wars in the Middle East have most recently brought the reality of UAS into the living rooms of the general public in the U.S. The most unfortunate depiction of these aircraft has been one of destruction and mayhem delivered from the air, watched by the unblinking eye of a camera, and activated by a person far removed from the results of a button push. The use of unmanned aircraft has evolved slowly into one, not only of destruction of ground targets, but the collection of intelligence, i.e. spying, using sophisticated sensors. Today, the general public and media have settled comfortably on the word "drone" as a catch all for anything that flies through the air without a pilot, leaving the perception of a wartime aircraft in the minds of the public.

A major premise for the American way of life (and constitutional rights) is not having ones privacy infringed upon in some form or fashion by a government agency. Regardless of whether it is on the Federal, state, or local level, this has been one of the prime obstacles to using unmanned aircraft in any scenario. Disaster scenarios present an exigent circumstance where one's privacy i.e., the freedom from unauthorized intrusion, may not be the most urgent issue and is possibly counter-productive as well. In these circumstances most citizens agree that aid should be rendered as soon as possible; with the tools and tactics required to do so.

This obstacle of negative public perception can be mitigated if unmanned aircraft are deployed in a framework of transparent utilization. This is accomplished by making the data and actual benefit available to the public. Public information would ideally include a very clear set of guidelines that describe when and where the UAS will be flown. The men and women responding to disasters and utilizing UA are the very individuals who can build trust in their communities and open the door to the use of unmanned aircraft when they are needed. Additionally, data retention guidelines should be clearly defined and made public as the exigent circumstance is resolved.

PRIVACY ISSUES

Public Opinion and Legislation

Invasion of privacy has emerged as a predominant rationale for restricting unmanned aircraft in the NAS. This key item has been used to halt almost every initial effort to deploy in many situations, much less a disaster situation. At least 38 states have enacted legislation of some sort directly aimed at curtailing the use of UA because of privacy concerns. Yet, technologies abound that could easily encroach in one's personal space and privacy. Examples include global earth imaging technology, camera phones, security cameras, red-light cameras, helicopters and small manned aircraft, to name a few. There is a stigma associated with drone use and invasion of privacy. It will take professional individuals, measured deployment, safety structures, evidence of benefit and real time data results to minimize such a stigma in the eyes of the general public and lawmakers.

It is interesting to note that many states promoted and passed legislation that, in general, left the door open for government agencies to use this asset as deemed necessary. A good example is the Texas House Bill 912[2]. This bill curtailed the ability of private individuals to gather electro-magnetic or visual imagery, or sensor data of any kind, but very specifically allowed the same use for fire, emergency responders, and law enforcement.

This type of measured response has been largely supported by the American public in polls conducted for the acceptable use of unmanned aircraft. The highest level of approval comes with the use of UA for search and rescue (SAR) at nearly a 90% approval rating, with pursuit of fugitive criminals near 75% and fire observation near 70%. It should also be noted that the same poll indicated a proportional disapproval rate for spying on U.S. civilians by any government agency. There is a direct correlation between the ways laws are being crafted and the general public's approval to use drones.

[2] Texas House Bill 912, D. Gooden, 09/13/2012

Data Retention

The Department of Homeland Security, in their review of UA for public use, detailed an extensive procedure for protecting the privacy of individuals involved in the process of testing UAS effectiveness and capability[3]. This document also addressed data retention, which is another component of the privacy issue. Major aspects involving "what to retain" and "what is the retention timeframe" of imagery collection are being debated. Scientific study and analysis typically requires retention and cataloging of collected data to provide baseline quantities or qualities and comparisons at a later date. Change analysis is a large part of the process in determining what contributed to any sort of negative or positive event that could occur in the future. This type of analysis can only be done over a span of time, with frequency being a factor, utilizing data retention. In many cases, time dictates what significant data is, what a significant geographic area is, and how the data can be used. One can see a future obstacle to obtaining and retaining UA imagery is the potential for legal liability. Litigation where the subpoena of images could assist one side or the other of a legal action could place the UA pilot or agency in an undesirable position. It can be recommended that data (images) be destroyed or erased immediately after their usefulness has been realized. If the decision is made to retain the data for any length of time, a well vetted legal chain of custody should be established and formalized for future eventualities and made public by the adopting agency.

Privacy in Exigent Circumstances

In the context of either a manmade or a natural disaster the privacy issue is somewhat nullified in that the benefit far outweighs the legal ramifications of collecting data that would assist in the saving of lives on a mass scale. Events such as the tsunami/nuclear disaster at Fukushima or the rebuilding of infrastructure after a hurricane such as Sandy on the east coast, or Katrina on the gulf coast of the United States could potentially dictate a suspension of the legal requirements now under consideration for data retention and subject matter. There is no real legal definition of disaster magnitude or scale for determination of this suspension of privacy laws; therefore, all laws remain in effect regardless of the potential loss of life, which is counter intuitive. The establishment of a Safir-Simpson like scale of disasters would provide a baseline at which "exigent" could become the condition(s) where UA are allowed to operate. The use of this scale would be fully recognized and accepted to collect specific data by manned or unmanned assets deployed to the disaster.

[3] Privacy Impact Assessment for the Robotic Aircraft for Public Safety (RAPS) Project , Dr. John Appleby, Nov. 16, 2012

PHYSICAL ISSUES

Visual Detection

There is no question that compared to manned aircraft, unmanned aircraft are more difficult to visually detect, not only for ground observers, but for pilots in manned aircraft as well. Because of their small size, in relative terms, this obstacle will have to be overcome electronically before any widespread use of UA occurs in mixed use airspace.

The Federal Aviation Administration (FAA) has published studies and documentation on the difficulty of full scale aircraft detection, by seasoned pilots in the cockpit, and has issued instructions on the best way pilots can scan their flight path for potential collisions, while simultaneously scanning the instruments within the aircraft.[4] All unmanned aircraft operations require that observers be used whose only task is to keep the UA in sight while maintaining visual observation of the airspace while on constant watch for manned aircraft. The observer is critical to the operation as he/she will call for flight abort, when necessary. The operator should recognize this requirement and make considerations for it in their aircrew requirements.

Human Factors

Extreme heat and extreme cold can be major obstacles to not only equipment such as batteries and electronics; it can also be an obstacle to efficient aircrew operation. Extreme cold can affect the observers and the pilot in command (PIC) in a visual line of sight (VLOS) condition by occluding vision. Extreme heat can cause dehydration, sunburn, and heat exhaustion which can be deadly to aircrew in remote areas or areas where aid could be delayed. The importance of a self sustained, climate controlled mobile command unit becomes apparent in these situations to allow even brief periods of respite for the aircrew. However, when hiking into wilderness areas, the aircrew should be provided the best options to maintain radio contact with the command center, i.e., satellite phones if necessary.

TECHNOLOGY ISSUES

ADSB, TCAS, Uncooperative Aircraft

A major obstacle to introduction of civilian UA into the NAS has been in the equivalent level of safety mandated by the Federal Aviation Administration. The most important issue is the ability for unmanned aircraft to sense and avoid (SAA) other aircraft whether they are manned or unmanned. It may seem contrary to a populist's belief, but the technology exists today allowing manned and unmanned assets to coexist in the national airspace.

[4] How to avoid mid-air collisions. P-8740-51, Federal Aviation Administration Library, Date : not listed

Currently, full scale aircraft are only required to report their position and altitude in certain classes of airspace and at certain high altitudes. General aviation has enjoyed relatively unfettered use of Class G airspace and need not even have a basic two-way radio on board to fly around an uncontrolled airfield, or if planned carefully, across the country. To the controlling agency, these vehicles are known as "uncooperative aircraft," not that they don't want to be cooperative, but they are not required to do so until they are in an airspace that requires identification and tracking.

The technology available to report position is known as automatic dependent surveillance-broadcast (ADS-B) and uses geo-synchronous positioning system (GPS) satellite technology. ADS-B is a cooperative surveillance technology in which an aircraft determines its position via satellite navigation and periodically broadcasts it, enabling it to be tracked. The information can be received by air traffic control ground stations as a replacement for secondary radar. It can also be received by other aircraft to provide situational awareness and allow self separation. The FAA is projecting ADS-B will be operational by the year 2020.

This ADS-B technology has its' own obstacles to overcome. Adoption by more than a limited number of aircraft by the target year of 2020 is questionable due to:

Limited bandwidth – The system uses a finite bandwidth that can only accommodate a limited number of aircraft at once.

System Security – ADS-B transmissions can be easily intercepted and "spoofed" to produce ghost aircraft and incorrectly report actual position of an aircraft.

Privacy - There are some general aviation concerns that ADS-B removes anonymity of the VFR aircraft operations. There is no 1200/1700 transmit ID used currently by transponder equipped aircraft to anonymously report position. This essentially allows the aircraft to be "visible" to air traffic control radar without the pilot having to actively identify his aircraft over the radio by the registered "N" number on the aircraft.

Economic Impact – The FAA reports that approximately 220,000 general aviation aircraft will be affected by this rule. The cost per aircraft is expected to be $10K-$15K.

The 2020 implementation date for manned aircraft is likely going to slip as the FAA struggles with other issues surrounding ADS-B. Implementation in UA would likely follow suit. It should be noted that even if full implementation were to occur, ADS-B would not be required for aircraft in class E or G airspace below 2,800' above ground level (AGL). Many small, general aviation aircraft would remain in this "uncooperative" category. This will likely be the major obstacle even in Class G airspace without a comprehensive plan for temporary airspace control or temporary flight restriction (TFR) enforcement in a disaster environment. The ability of unmanned aircraft to "sense and avoid" any aircraft at any time, in the airspace below 2500'

AGL is reported to be the only acceptable solution to the FAA. It will be up to the UA industry to provide this solution.

REGULATORY

Federal Regulations

Since February 7, 2007 the FAA has essentially grounded all civilian unmanned aircraft operations. The agency has been slowly working towards a method to allow "public" aircraft to be utilized in certain situations with the application of a Certificate of Authorization (COA) or, a Waiver, being the preferred method. The obstacle to this process is that it can be a lengthy, time consuming process and requires a considerable level of commitment to meet the guidelines currently set forth for qualification. In forming an aircrew, an agency can expect to build a team around at least one certified pilot with the proper medical certification, develop standard operating procedures, a maintenance program, and the ability to properly train all aircrew members. This training and proficiency flights would also serve to keep them rated and qualified to operate the unmanned aircraft chosen.

As of late, the FAA has begun issuing exemptions under Section 333 or the original Re-authorization bill. While these waivers do allow for commercial UA operations, there is still a lengthy period before approval – the very least has been 120 days for a "normal" application. For most, the option also requires locating an aviation lawyer (not a requirement!) to generate and submit the application to give it the necessary gravitas to be considered by the FAA. For the most part, these applications still require a Certificate of Authorization, but the FAA has changed their stance and have allowed current holders of 333 exemptions to fly without a COA as long as the operations are under 200' AGL.

State Regulations

State regulations are starting to appear and could supersede the restrictions as required by the Federal Aviation Agency. Currently, most state regulations are centered on protecting the privacy of its citizens and not so much the operations or qualifications of the aircrew personnel. During any disaster this could present itself as an obstacle to insertion by a simple misinterpretation of the boundary of state regulation and federal regulation. In a disaster of significant enough proportions to require federal intervention, state rules would likely be superseded by federal rules. Of the states that do have some form of regulation, they vary from only token restrictions to an outright ban on unmanned aircraft use in municipalities and even in other unincorporated areas. Examples of states with regulation are as follows*

State	Action	Notes
Alabama	Restricts UA use	Provisions made for private use for wildlife management
North Carolina	Restricts all UA use	Two year moratorium on drone use
South Carolina	Restricted use legislation passed House unanimously	Legislature adjourned before further action taken
Texas	Legislation restricting use enacted September 2013	Provisions made for law enforcement and other first response agencies

* Full listing available at https://www.aclu.org/blog/technology-and-liberty/status-2014-domestic-drone-legislation-states

It is significantly easier to list the states that have a designated controlling authority for unmanned aircraft use because at the time of this writing, there are so few: Most certainly there are other states considering some sort of controlling agency even if might fall to the state law enforcement agencies such as the Department of Public Safety (DPS) in Texas.

State	Agency	SOURCE
North Dakota	North Dakota Aeronautics Commission	http://www.nd.gov/ndaero/
North Carolina	Division of Aviation	http://www.ncdot.gov/aviation/

SYSTEM LOGISTICS

Systems logistics obstacles consist primarily for the supporting equipment a UA requires for successful operation in a disaster scenario. Batteries, parts, cameras and other sensors can fail in the field. Back-up kits are necessary. As a rule of thumb, the larger the aircraft (more complex) the more likely obstacles will be encountered during deployment. Smaller UAS can be supported easily out of a backpack for a number of missions. Eventually the aircrew will require a retreat to an area of support for re-supply of essentials. Whether it is batteries, data drop off, or food and water for the aircrew it will always be a consideration. In disasters of the severest kind, such as Hurricane Katrina on the Gulf Coast or Hurricane Sandy on the east coast, a self contained system could be used for early insertion, albeit with range/coverage limitations. Other obstacles could fit into the categories listed below:

Moving to the scene – This can be an issue in widespread disasters such as flooding and hurricanes. Major thoroughfares can be inundated with water. Conversely, those not inundated could be choked with a population fleeing the area. Even with some warning, major highways were grid locked in the face of Hurricanes Katrina and Ike.

Resources available – The unmanned aircraft system may need to be completely self sufficient with fuel, food, potable water and biological facilities and all necessary supplies to maintain an operation.

Duration of the event – The duration directly affects "*Resources available*" and can also test the endurance of the aircrew performing the operations.

UNMANNED AIRCRAFT OPERATING AREAS / PHYSICAL ENVIRONMENTS

When considering using UA, the operating or physical environment plays a major role in determining potential risks and obstacles vs. benefit gained by this technology. This section will center around four main areas of operation and the difficulties encountered in each. It could be said that, in ascending order of challenge, they could be listed as follows:

1. Rural/Unpopulated
2. Semi-Rural/Low Population Density
3. Suburban
4. Metropolitan

While flight operations have similarities, each of these areas may have significantly different requirements for the categories of airspace management, logistics, support, and infrastructure. Simply stated, the higher the population density, the higher number of safety measures required for a flight. For purposes of this document we will consider the following densities for each area[5] as outlined in Table 1:

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[5] U.S. Dept. of Transportation, Census Urbanized Areas and MPO/TMA Designation, Vincent Osier, 04/04/12

Table 1: Areas and Population densities

Area	Population Density (persons/ square kilometer) – PLEASE CHECK NUMBERS
Rural/Unpopulated Areas	0-9 per square mile
Semi-Rural/Low Population Density	10-100 per square mile
Suburban	101-500 per square mile
Metropolitan/City	501+ per square mile

Rural/Unpopulated – Unpopulated areas can be the easiest to conduct flight operations in for a multitude of reasons. Fewer obstacles exist such as privacy issues, little risk to people or property, easy identification of airspace encroachment by manned aircraft and ability to abort flight rapidly if needed, etc. Rural areas also tend to have the highest impact on logistics and support. This area is most likely the best candidate for UA use due to economy of scale. It is sometimes very difficult to utilize manned aircraft in a remote area for a long period of time due to fuel constraints, jurisdiction, and overall economy. Typically these areas are in Class G airspace in the NAS, are considered "uncontrolled" airspace and demand fewer operational requirements for the operator. From a flight operations standpoint, Class G airspace is the easiest to operate in, but is still not without some hazards. These areas are typically desert, agriculture land, open prairie, forest, canyons or high mountainous areas. It is a given that the likelihood of a disaster, affecting large numbers of people, occurring over a large area of farmland is low and not really of concern to UA operators in this context. There can, however, be floods, fires, storms or missing individuals whose responders could utilize unmanned aircraft for mitigation support. Scenarios where flooding or fire could move from these environments in the direction of more populated areas require the most planning from a logistics standpoint, and can require an unmanned aircraft team to be as self sufficient as possible. From an event tactics view, the largest obstacle can be the lack of communications, followed by the need for power sources, food, water, rest facilities and the possibility of injuries to team members, especially when deployment is to very remote areas. This is the most common area for use of UA in Search And Rescue (SAR). The risks are low and the return can be significant.

Semi-rural or low density population – These areas can be less of a challenge logistically because they may be nearer to, or at least within comfortable reach of, some infrastructure or small town. In the context of wild land fires, this is where the wild land urban interface (WUI) becomes more of a concern to public officials in a disaster scenario and where unmanned aircraft can contribute immensely. This zone can have a significant increase in population density located very close to undeveloped or forested areas. Consequently, there is more immediate concern for the safety of people living there due to increased, but spotty populations.

In a disaster event there is likely to be more exposure to "non-participants" during the actual mitigation process. A non-participant can be categorized as civilian curiosity seekers, media and media aircraft, and uncooperative general aviation aircraft. Non-participants can become obstacles impacting the safety of flight operations, crew well being, and public perception of the operation. Non-participants impact can be minimized by implementing procedures such as isolation of the operation through the use of police or other agency cordons, obtaining temporary flight restrictions, etc. If a flight crew must be utilized for safety management then it is incumbent on the pilot in command (PIC) to ensure that all facets of flight responsibility are executed.

It is in this environment that you will likely find the event operating under the National Incident Management System or Incident Command System (NIMS/ICS). The integration of UAS into the NIMS protocol is not yet clearly defined, however every flight crew should be NIMS certified to a minimum level[6], as this is the system under which the federal agencies and most municipal agencies operate under during an incident. This system generates an incident action plan (IAP) that calls for and establishes communication pathways between all participating in the event.

Another obstacle is not unique to UAS operations, but can be life threatening. The inter-operable communications between participating agencies can be very good or non-existent, depending on the agencies. Radio frequencies, computers, other handheld devices, or a very detailed communication plan needs to be coordinated so that effective communication can take place between the controlling agency and the UA flight crew.

Suburban Environments – For the most foreseeable future, UAS operations in the suburban and metropolitan environments would have to be under emergency circumstances. In suburban environments the safety exposure experienced by the UA operations takes a leap by an order of magnitude. Considering the "do no harm" credo, the benefits must far outweigh any risks involved with the utilization of UA in suburban areas. In this context we will assume operations would be due in part to some severe catastrophe along the order of the Moore, Oklahoma tornadoes that struck in May of 2013. That event made other obstacles evident when inserting a UA post-disaster. Although this is not an exhaustive list, these issues would have contributed heavily against the use of unmanned aircraft without comprehensive training and response experience:

[6] Minimum NIMS training should at or above IS700. A, National Incident Management System (NIMS) An Introduction, http://training.fema.gov/is/courseoverview.aspx?code=IS-700.a

1. Destruction of communication infrastructure – cell phone switches and operations were disrupted by the storms effects.

2. Civilian aircraft in large numbers in the air over Moore – the number of media and civilian aircraft attempting to operate in the immediate area over Moore was so intense that a temporary flight restriction (TFR) had to be issued by the FAA to restrict the airspace to only those aircraft necessary to mitigate the disaster.

3. Lack of communications inter-operability – many disparate agencies such as police, sheriff, fire, emergency medical and then ultimately the Federal Emergency Management Agency did not share a communal operating RF frequency.

4. Lack of a common overall disaster situational picture – While NIMS protocols do indeed help with the organization of resources deployed, and it was utilized in Moore, the inability to produce an overall disaster situational picture that displays or reports all resources and their locations was and is still unavailable.

When a suburban area is threatened by disaster such as wild land fires, there are other obstacles that could preclude the operation of unmanned aircraft, not the least of which is the amount of spurious radio frequency (RF) energy in the areas of densely populated areas. Cell phone towers, home computer routers and video transmission systems can overwhelm RF during and after a disaster. The largest contributors would be in the 2.4Ghz and 5.8Ghz where most consumer routers, wireless phones, and consumer electronics operate. Additionally, microwave and cellular RF could potentially jam GPS navigation systems by “swamping” a wide band of radio bandwidth. That same bandwidth is required for safe operation of autopilots in some systems.

Metropolitan – For the time being, the high rise area of a major metropolitan city has such an abundance of obstacles that without mitigation measures in place; including those described previously in the suburban environs, it is unlikely UAS would be utilized, unless an exigent situation occurs. However this scenario is changing as even commercial uses are being explored for UA to operate in the “concrete canyons” well below any general aviation. Disasters such as earthquakes, storms, floods, brown cloud detection and even building collapse, could be events that would benefit from the smaller unmanned aircraft that can hover and carry sensors considered “non-typical” into these areas.

The most critical obstacle to operating in this environment would be in the radio frequency category. Most civilian UA command and control systems operate at their optimum in the visual line of sight (VLOS) range. For best operation there should be an unobstructed view of both the receiving and transmitting antennae on the aircraft and ground station. Even when unmanned aircraft are flown over tall buildings there is a reduced angle at which the aircraft can be operated and still maintain visual contact. Most UAS rely on the GPS constellation of satellites for navigation. Tall buildings can block satellite signals, quite effectively rendering navigation capabilities compromised at the very least, and non-existent in the worst case.

The second obstacle is never given much operational consideration. Tall buildings can create their own weather due to their proximity to one another and wind currents. Two buildings standing close together can create wind currents aloft that would go unnoticed until the aircraft enters them, when it could be too late. The rotor effect from sharp, square edges and the acceleration factor of wind between buildings can quickly exceed the capabilities of the aircraft's control which could result in an accident.

Population density can be a very real concern to UA operations in this environment. You could conceivably have people in mass in an evacuation mode under your flight operations. If sufficient separation cannot be made, the flight operations may have to be curtailed to ensure the safety of those fleeing the disaster.

UNMANNED AIRCRAFT TYPES

There are wide selections of small civilian UAS platforms that are beginning to show on the market today that could be used in a disaster situation. For the purpose of this document most civilian UA work can be broken into three broad categories. In order of applicability and market penetration, the types are fixed wing, rotor wing, and lighter than air or dirigibles. These aircraft have different applications and are utilized in different environments. The very physics that allow them to fly can be an obstacle given the environment where the UA is flown. This section will address the appropriate application of the technology and the obstacles to be overcome. To clarify, all unmanned aircraft systems share an inherent obstacle in that there are currently no flight control systems that have a built in sense and avoid system for other aircraft (manned or unmanned) or the ability to avoid or overcome objects in their flight path. This would be categorized as a navigational obstacle.

Fixed Wing

The small fixed wing unmanned aircraft can come in many different configurations from one pound up to 55 pounds. Launching and landing all but the smallest of these aircraft requires a certain amount of open space to launch and land as they typically do not have vertical takeoff capabilities, though there are a few on the market. This type of aircraft would lend itself well to the rural and semi-rural applications as they can cover large amounts of area most effectively and efficiently. The suburban and metropolitan areas would present obstacles for fixed wing UA such as buildings, telephone and electrical wires and lack of clear, open space. Metropolitan and suburban areas would present physical obstacles to safe takeoff and landing of the fixed wing. That being said, a well-skilled pilot can land a fixed-wing aircraft on a city street avoiding telephone poles and wires, once a safe perimeter has been identified and cleared. The smaller UA would not damage infrastructure in an impact, though the aircraft could be destroyed. This can be an acceptable loss during the emergency phase post-disaster.

Rotor Wing

Full scale rotor wing aircraft have long been recognized as a SAR workhorse and the *go to* asset for disaster mitigation. In no way will a small unmanned aircraft diminish that role. The real limitation for a small unmanned multi-copter today is its very short flight duration. This short duration can also be made shorter by the amount of wind the aircraft is flying in or the payload it is carrying. The rotor wing expends most of its energy to stay in the air and it stands to reason that wind will only tax power sources even more. This limitation is an obstacle that will be overcome by technology, but today is a very large obstacle for rotor wing or vertical takeoff and landing (VTOL) aircraft. In comparison to the fixed wing aircraft, the areas of rural and semi-rural would present an obstacle due to the sheer size and the area to be covered by the aircraft. However using a rotor wing would be advantageous where a prolonged hover is required. Rotor wings are frequently labeled as quadcopters, hexacopters or octocopters, depending on the number of arms and motors.

Other Aircraft Types

Lighter than air (LTA) ships have much improved control abilities compared to the “blimps” of the past. New designs in the shape and structure of the airship have increased its ability to fly in some wind. Regardless, this aircraft type is affected by weather significantly more so than the previous two. Most LTA’s are used for persistent stare operations where a very long duration is required. An obstacle to this type of aircraft is the overhead required to maintain the ground equipment and the helium required to fill the bag. They can be rather large, which is necessary to accommodate the amount of helium needed to achieve adequate buoyancy to loft a payload and maintain flight. This makes them difficult to transport to a site in a ready to fly state. However, when tethered, LTA’s are classified differently by the FAA REF and offer opportunities not available with other UAS.

Table 2 summarizes the general characteristics of UAs and their applicability in different usage scenarios. While specifics vary between platforms the table highlights some advantages nd limitations

Table 2: Applicability of UA Technologies

UA Type/ Area Type	Rural/Unpopulated Areas	Semi-Rural/Low Population Density	Suburban	Metropolitan/ City
Fixed Wing	Yes	Yes	Yes	Negative: 1. Landing 2. VLOS
Rotar Wing	Potential limited range	Potential limited range	Yes	Yes
Lighter than Air	Potential limited range	Yes	Yes	Potential impact of tall buildings

NATIONAL INCIDENT MANAGEMENT SYSTEM (NIMS)

Most all large scale disasters are responded to under the National Incident Management System (NIMS) or Incident Command System (ICS). The NIMS system was developed by the Federal Emergency Management Agency (FEMA) to provide a structured chain of command and areas of responsibility that can be expanded or collapsed as the situation calls for. There currently is an area of responsibility to control "Air Assets" which to date has consisted of managing manned air assets only. The major obstacle in this system is that NIMS operations protocols are not in sufficient detail to provide any segregation between manned and unmanned air assets. While unmanned aircraft have been available for some time, and have operated in some disasters, they have also caused enough concern in the incident management system that their services have been refused. This is another area where the manned aircraft bias applies because only manned aircraft are considered for response under this system.

SUMMARY

While there are certainly many obstacles to insertion of unmanned aircraft into a disaster situation, the benefit to risk ratio places this asset in a highly desirable position. In many cases, privacy issues will be far outweighed by the need for urgent response to provide aid and restore infrastructure. Segregation of airspace is the most reasonable approach to unmanned aircraft use and a controlled airspace scenario is the ideal place to prove it. Additionally, the technological requirements of ADSB, TCAS, and other emerging technology utilization by all aircraft in the area can easily be enforced to further enhance the "sense and avoid" capability desired for the equivalent level of safety sought in mixed airspace use.