A New Paradigm for Small UAS[*]

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Small Unmanned Aircraft Systems (UAS) are different than almost any other kind of aircraft. They can fly in places where no manned aircraft flies or where it would not be desirable to fly. They also pose different risks based upon their small size and performance. Today, the FAA regulates all navigable airspace, which extends to the ground. Within this airspace, there are some areas in which manned aircraft are simply not capable of flying by existing Federal Regulations. This may include areas that are very close to the sides of buildings, under bridges, below tree cover, and near power cables. Our research envisions that small UAS might make use of this airspace, which would be considered non-navigable by traditional manned aircraft due to the proximity of obstacles. Additionally, a small UAS may weigh only ounces. An aircraft that small is likely to pose a vastly different risk to people and property on the ground than would manned aircraft. Considering usage of airspace and the associated risk in this manner represents a departure from current thinking and may influence the methods of regulating these new aircraft. This paper explores and discusses this potential new paradigm further, and illustrates the implications with a set of operational scenarios.

1. INTRODUCTION

There is much interest in safely flying Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) along with manned aircraft, and efforts are underway to determine how best to do so. The purpose of this paper is to explore a new concept for safely flying small UAS in places where manned aircraft cannot safely fly or where it would not be desirable for manned aircraft to fly. We will refer to these operations as "new paradigm operations".

Over one hundred years ago, the Wright Brothers were the first to achieve controlled, sustained, and powered heavier-than-air human flight: a major aviation revolution. For the next century, with a few exceptions for narrow military operations, aviation continued to evolve with a central assumption being that the pilot-in-command was on-board the

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aircraft. With the widespread introduction of unmanned aircraft*, we are entering another aviation revolution.

Unmanned aircraft systems (UAS)† have transformed how the military conducts operations and is starting to have an impact on other areas including homeland security, law enforcement, public safety, and scientific research. A host of commercial and other public interest missions are envisioned. [1]

In 2006, Nicholas A. Sabatini, then the Federal Aviation Administration's Associate Administrator for Aviation Safety observed that "the development and use of unmanned aircraft systems is the next great step forward in the evolution of aviation". The contrast in Mr. Sabatini's observation is important. A *great step*, which is essentially a revolution, and an *evolution* are two very different things. The removal of the pilot from on-board the aircraft is a fundamental change to the paradigms that define today's aviation. It will be a challenge to integrate UAS because the technical standards, operational procedures, and policy regulations of our aviation system are structured to enable gradual evolutionary changes in a fashion that continuously ensures and extends safety.

Manned aircraft and operations are divided into various groupings and governed by different regulations due to the nature of the design and how they are operated: jet vs. propeller, small vs. large, fixed wing vs. rotorcraft, multi-engine vs. single, piston vs. turbine, instrument flight rules vs. visual flight rules, private vs. commercial, etc. Given that unmanned aircraft may not be large enough to carry a human pilot on-board, there is an even greater potential for variance in both size and performance. Thus, a broader set of methods for regulating these aircraft should be considered.

Large military unmanned aircraft have been in the news, with significant attention being devoted to large unmanned aircraft like the Predator (MQ-1), the Reaper (MQ-9), and the Global Hawk (RQ-4) which are used to both surveil and strike targets with bombs and missiles in oversea locations. These aircraft are similar in size to manned aircraft.

In this paper, we look at an entirely different class of UAS—small UAS—which could weigh ounces or for the purposes of this paper can weigh up to 20 pounds, whose payload consists of a camera or other similar type of sensor. These aircraft are much smaller than an aircraft capable of carrying a human pilot; much smaller than an ultra-light aircraft, which can be as large as 254 pounds.[2]

Because of their small size and in many cases very low airspeeds, can small UAS operate in airspace where manned aircraft would not be able to operate?

Section 2 gives three examples of sUAS future scenarios that illustrate potential new regimes. Section 3 describes small UAS characteristics with some specific examples.

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* Unmanned aircraft are defined by the RTCA as an "aircraft operated without the possibility of direct human intervention from within or on the aircraft." [1]

† Unmanned aircraft systems (UAS) include the airframe, the control station, the command and control communications link, and potentially launch and recovery elements.[1]

Section 4 identifies aviation risks specific that generally must be addressed for safe flight. Section 5 presents a philosophy for mitigating these risks for small UAS in new regimes. Finally, Section 6 summarizes the key points of the paper.

2. EXAMPLE OF SMALL UAS FUTURE SCENARIOS

Imagine the following future hypothetical situation :

Following heavy rains and landsides, the state's department of transportation is concerned about the structural integrity of a bridge for a major highway over a deep gorge. Minor cracks that did not affect structural integrity were observed in other bridges along the highway's route. The highway must remain closed until the deep gorge bridge's safety can be verified. Rather than having to wait until safety scaffolding can be constructed and the bridge can be visually inspected (a process that could take weeks), civil engineering inspectors are able to deploy a 10 pound unmanned aircraft affixed with a specialized sensor. The unmanned aircraft can automatically fly a scan pattern under and right next to the bridge collecting data that can be analyzed in a couple of hours. The department of transportation saves money and is able to reopen the bridge in hours rather than weeks reducing the impact on drivers.

Or another hypothetical situation:

Following a minor earthquake over 100 miles away, the National Park Service is concerned about cracks in the Washington Monument. In the past, they have hired civil engineers to rappel down the side of the monument to inspect cracks. This time, they are able to deploy a 10 pound unmanned quadcopter affixed with specialized sensors to automatically fly a scan pattern to assess the damage. The inspection takes a fraction of the time, costs significantly less, and does not put any lives at risk.

Or one last hypothetical situation:

Police in a major east coast city are called to the scene of a domestic disturbance in an apartment building. Officers are told that a man, despondent over the death of his only child, is threatening people with a hand gun. The on-scene commander is concerned about potential hostages and whether the man is attempting to die in a blaze of glory. One of the first officers to arrive on the scene deploys a quadcopter to fly quietly alongside the outside of the apartment building and near-by closed windows. The police are able to observe the man in his apartment and conclude that there are no hostages and the man does not in fact have any weapons. With the confidence of the real-time intelligence, police are able to force entry into the apartment and subdue the man without incident or injury.

In all three of the above examples, a small UAS is operated in airspace where manned aircraft are not able to fly because it is too close to ground features and obstructions. In addition, the risk to people on the ground could also be minimized (e.g. controlling access to the ground area under the small UAS operation). Section 5 details how small

UAS might operate in a new aviation paradigm that does not introduce additional risks to people on the ground or other aircraft. [3]

3. SMALL UAS DESCRIPTION

Small UAS introduce a completely new vehicle type to the National Airspace System (NAS). Manned aircraft must be large enough to carry at least one person—the pilot. With unmanned aircraft, there is no minimum size. Size is determined by the limits of technology and the payload (usually a sensor). Currently, the US military is using unmanned aircraft operationally that are as small as one pound. As an example, the AeroVironment Micro Air Vehicle WASP is a lightweight, fixed-wing aircraft with a two-bladed propeller driven by a small electric motor (see Figure 1). It weighs less than a pound, has a wingspan of just over 28 inches, a maximum speed of 35 knots, and can operate from just above the surface up to 1000' above ground. It is equipped with an internal Global Positioning System/Inertial Navigation System, autopilot and two onboard cameras. The entire system can function automatically from takeoff to recovery, or can be remotely controlled by one pilot using a handheld control unit.[4]

Figure 1. WASP by AeroVironment
(Photo - USAF Fact Sheet)

Figure 2: DraganFlyer X4
(Photo - DraganFly website)

Another example is the DraganFlyer X4, made by DraganFly Innovations, Inc., which is a quad-copter, vertical take-off aircraft, driven by four small electric motors (see Figure 2). It weighs 24 ounces, is 25 inches wide, and can operate from a hover to 30 knots. It is equipped with a suite of on-board sensors and an advanced flight computer that permit it to stabilize itself in flight and be flown automatically or manually. Its 8-ounce payload can consist of a variety of camera modules, including optical and thermal sensors.[5]

These are only two examples of the sophisticated capabilities that are becoming available for relatively low cost in the small UAS market.

The U.S. Federal Aviation Administration (FAA) is currently in the process of developing a set of rules that would enable the routine operation of small unmanned aircraft for commercial purposes. A notice of proposed rulemaking (NPRM), which will become part 107 of the Code of Federal Regulations for Aeronautics and Space (14 CFR), is expected to be published in the Summer of 2012. While this is a major development to enable the operation of UAS for commercial purposes, the new rule is expected to largely follow the spirit of today's regulations for manned aircraft. It will apply only to aircraft operating in visual line of sight of the pilot on the ground to avoid collisions with other aircraft. The rule is not expected to explicitly address the notion that UAS could operate where there is virtually no risk of collision with manned aircraft due to their unique characteristics, and that their size may pose minimal risks to people and property on the ground. Based on the recommendations of the Small UAS Aviation Rulemaking Committee (ARC), a committee chartered to make recommendations to the FAA regarding a small UAS rule, the new rule is likely to apply to unmanned aircraft weighing less than 55 pounds that operate in daylight and visual metrological conditions.[6] The new rule is **not** expected to address the operation of small UAS beyond visual line-of-sight of the pilot or observers on the ground. Beyond visual line-of-sight operations are important to enable many potential commercial and public safety applications.

For the remainder of this white paper, a small UAS is defined by the authors as an aircraft weighing less than 20 pounds that either tele-operates (i.e., flown remotely by a pilot on the ground) or automatically operates under the direct supervision of a pilot on the ground.

4. AVIATION RISKS

Risk is defined in aviation as the likelihood of a hazard causing an undesirable incident combined with the severity of the incident. Since the most severe incident involves death or injury to persons, we will focus on hazards where this is a potential outcome. In an aggregate sense, there are three major risk categories in aviation:

a. Death or injury of persons **on board subject aircraft**, resulting from a mishap,
b. Death or injury of persons **on board another aircraft**, resulting from a mid-air or surface collision between two or more aircraft/ground vehicles
c. Death or injury of persons **on the ground** (not in an aircraft or vehicle involved with a collision) resulting from a mishap or collision.

These risks are managed by the certification of aircraft, the licensing of airmen, and by the establishment of operational rules. For small UAS, there are some unique circumstances that influence and mitigate these risks, and shape the new regimes under which they might fly.

5. MITIGATING AVIATION RISKS FOR SMALL UAS OPERATED UNDER THE NEW PARADIGM

Conceptually, small UAS can fly in places where no manned aircraft flies, or where it would not be desirable to fly. Examples include very close to the sides of buildings, under bridges, below tree cover, and near power cables. This section presents a conceptual exercise, focused on examining the operational, technical, and policy issues with unmanned aircraft flight in "new regimes" – airspace where no manned aircraft can fly or would want to fly, i.e., non-navigable airspace. See Figure 3.

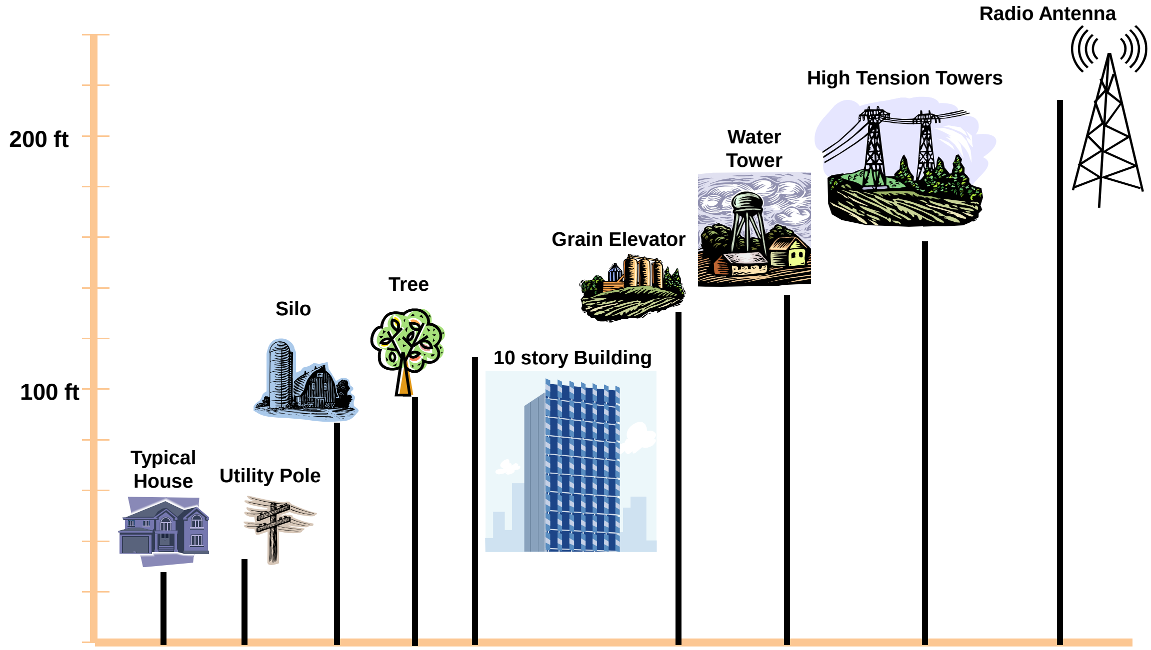

Figure 3: Typical Heights of Common Obstacles

The FAA is responsible for ensuring the safe, efficient, and secure use of the Nation's airspace. This responsibility is focused on regulating and operating navigable airspace, which is defined as airspace at and above the minimum flight altitudes prescribed in regulation, including airspace needed for safe takeoff and landing.[7]

To identify possible new flight regimes where small UAS might be able to safely fly, we focused on locations where manned aircraft are not permitted to fly. Consider the FAA's rule for minimum safe altitudes, 14 CFR 91.119, which states:

"**91.119 Minimum safe altitudes: General.**
Except when necessary for takeoff or landing, no person may operate an aircraft below the following altitudes:

(a) Anywhere. An altitude allowing, if a power unit fails, an emergency landing without undue hazard to persons or property on the surface.

(b) Over congested areas. Over any congested area of a city, town, or settlement, or over any open air assembly of persons, an altitude of 1,000 feet above the highest obstacle within a horizontal radius of 2,000 feet of the aircraft.

(c) Over other than congested areas. An altitude of 500 feet above the surface, except over open water or sparsely populated areas. In those cases, the aircraft may not be operated closer than 500 feet to any person, vessel, vehicle, or structure.

(d) Helicopters, powered parachutes, and weight-shift-control aircraft. If the operation is conducted without hazard to persons or property on the surface—

(1) A helicopter may be operated at less than the minimums prescribed in paragraph (b) or (c) of this section, provided each person operating the helicopter complies with any routes or altitudes specifically prescribed for helicopters by the FAA; and

(2) A powered parachute or weight-shift-control aircraft may be operated at less than the minimums prescribed in paragraph (c) of this section."[8]

Figure 4 shows a physical device that one Federal aviation research agency created to artificially create non-navigable airspace. Essentially, a four sided square of netting with a net ceiling was built to ensure that any small UAS operated in the "airspace" will not be a collision threat to other aircraft.

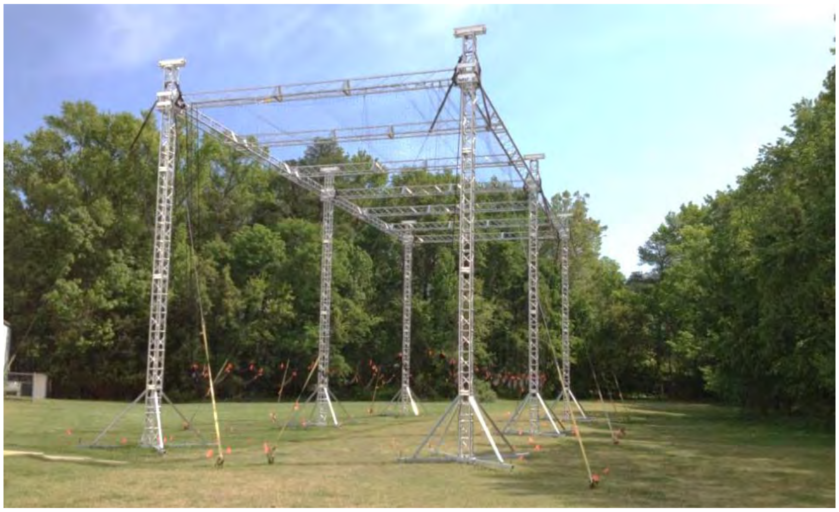

Figure 4. Device Deployed by a Federal Aviation Research Agency to Creat Non-Navigable Airspace with Nylon Netting Held up by Scaffolding.
(Photo– Andrew Lacher)

This paper is concerned with flight of a small UAS where it would be impossible for any manned aircraft to obey 14 CFR 91.119, but still possible for small UAS to comply due to their small size, lower speeds, and increased maneuverability.

If a small UAS is restricted to operating in areas below or very near obstacles, can the risk of a mid-air collision be reduced to an acceptable level?

The most maneuverable manned aircraft are rotorcraft, which are permitted to fly almost anywhere that they can comply with the rule to not create an undue hazard to persons or property on the surface. Thus, the airspace considered in this research is necessarily restricted to volumes very close to persons, property, or other hazards to manned aircraft, such as ground obstacles. This is contrary to the usual operating mind-set that dictates aircraft should stay away from obstacles – for small UAS operating under the potential new paradigm, the goal is to operate close to obstacles, because manned aircraft will not be operating there.

Some potential small UAS missions would actually require this kind of proximity. Examples of useful commercial activities include: close-up power line monitoring, building/bridge inspection, beacon light and radio tower servicing, law enforcement, window washing, tree trimming, and other operations very near obstacles. Heights of some typical obstacles are illustrated in Figure 3. It should be noted that these heights are well below the standard minimum operating altitudes of nearly all manned aircraft, and it is in the proximity of these types of obstacles that creates the new regime where small UAS missions could be operated.

Let us specifically look at the three risk categories identified in Section 2, that is, the risk of death or injury of persons:

a. On-board the aircraft
b. On-board another aircraft
c. On the ground

The subsections below will discuss the mitigation approach for minimizing the risk category following the potential new paradigm associated with a small UAS operating in non-navigable airspace.

Risk to Persons On-board the Aircraft

Given that the small UAS is too small to carry a human whether a pilot or a passenger, there is **no** risk of death or injury of person on-board the aircraft. Thus, the mitigation for this risk is that there are no people on board.

Risk to Persons On-Board Another Aircraft

Death or injury to a person on-board another aircraft could result from small UAS that is involved with a mid-air collision. In general, there are a number of standard factors that reduce the risk of mid-air collisions among traditional manned aircraft including operating rules and airspace structure, air traffic control services, visual see and avoid, and the Traffic Alert and Collision Avoidance System. See the middle column in Table 1. For the most part, these four standard factors would not serve as effective mitigations for small UAS operating in non-navigable airspace. See the right column in Table 1.

Given Table 1, additional mitigations would be required to minimize the potential for midair collisions between a manned aircraft and a small UAS operating under the new paradigms postulated by this paper.

For small UAS operating in visual line-of-sight of the pilot, the pilot will still be able to "see and avoid" potential intruder aircraft.[5] At the same time, encounters are minimized since manned aircraft should not be operating in the vicinity of obstacles and obstructions. As an example, a fixed wing aircraft according to 14 CFR 91.119 must remain "at altitude of 1,000 feet above the highest obstacle within a horizontal radius of 2,000 feet of the aircraft." If the UAS remains within 2000 feet from and no higher than the highest obstacle, then the manned aircraft should pass above with sufficient clearance[*]. If the small UAS remains very close to the obstacle (e.g., within 50 to 100 feet) most aircraft even rotorcraft are not likely to be able to safety operate in that space. Essentially, the obstacle protects the airspace enabling the safe operation of small UAS. Let us examine Figure 4 again. Notice that the agency happened to build the net/scaffolding structure in a cleared field within 100 feet of trees on three sides and a building (not pictured) on the fourth side. The airspace is already essentially non-

[*] The altitude of 1000 feet above the highest obstacles is subject to pilot judgment and may not be uniformly applied in a precise fashion.

navigable. If a small UAS was to operate in this area without netting and remain below the tree line, it would be in naturally created non-navigable airspace.

Table 1. Standard Mitigation Factors and the Impact on New Paradigm Small UAS

Standard Factor	Manned Flight Mitigation	Impact on Small UAS Flying under the New Paradigm
Operating Rules and Airspace Structure	There are a number of procedures that have been established to minimize encounters among aircraft. These include ordinal altitudes[*], traffic patterns, airspace class definitions, and right-of-way rules.	A large portion of new paradigm small UAS will be flying in Class G airspace, away from airport traffic patterns, and below an altitude where interaction with manned aircraft would be a factor.
Air Traffic Control	ATC services are provided only in classes A, B, C, D and E airspace[†]	A large portion of new paradigm small UAS will be flying in Class G airspace where ATC services are not available. For those operating in Class B, C, or D airspace, they would be operating only in locations where manned aircraft would not be flying.
Visual See and Avoid	"When weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft." [9]	While some new paradigm small UAS may operate within visual line-of-sight of the pilot this may not be true of all operations. In addition, the pilot of potential intruder aircraft will most likely not be able to visually acquire the small UAS due to its small size. Nevertheless, the desired result would be achieved by avoiding the portions of airspace where manned aircraft are flying.
Traffic Alert and Collision Avoidance System (TCAS)[‡]	An automated system for pilots that alerts them to near-by traffic and in can provide them an advisory on a vertical avoidance maneuver. [10]	Near the surface (below 1000 feet) TCAS functionality is limited and should not be relied upon as mitigation.

Technology could be employed that would keep the small UAS from straying outside the boundaries of the trees. One potential technical approach is altitude and geo-bounding the flight using robust flight control software on-board the small UAS.

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[*] The proper cruise altitude is determined by magnetic heading of the aircraft.

[†] Class G airspace is defined as the portion of the airspace that has not been designated as Class A, B, C, D, or E. Class G airspace extends from the surface to the base of the overlying Class E airspace typically 700 or 1200 feet above ground level (AGL)

[‡] "TCAS was developed to reduce the risk of mid-air collisions between aircraft." TCAS I (which provides traffic advisories) is mandated for use in the U.S. for turbine powered, passenger-carrying aircraft having more than 10 and less than 31 seats." TCAS II provides traffic advisories and resolution advisories that are "recommended escape maneuvers, in the vertical dimension to either increase or maintain the existing vertical separation between aircraft. TCAS II is mandated by the U.S. for commercial aircraft, including regional airline aircraft with more than 30 seats or a maximum takeoff weight greater than 33,000 lbs."[9]

Perhaps a sensor could be put on the small UAS that ensures that it would not stray from the structure serving as the obstacle protecting the airspace as non-navigable. Lightweight LIDAR[*] [11] technology could be used not only for collision avoidance with the obstacle but to keep the UAS within a maximum range of the obstacle.

What is the appropriate technology to ensure that the small UAS operating under this new paradigm remains in non-navigable airspace protected by an obstacle?

There still may be a small risk of a mid-air collision if the small UAS fails to remain within the non-navigable airspace (safe range of the obstacle) together with an independent failure of command and control link preventing the remote pilot from recovering the aircraft. In the event of a collision, the small size and frangibility of the small UAS may not result in a catastrophic loss.

In August of 2011, a US C130 collided with a RQ-7, Shadow, in Afghanistan. [12, 13] While there was some damage to the C130 and the RQ-7 was a total loss, the C130 was able to land safely with no injuries. The RQ-7 struck the wing of the larger aircraft. Perhaps if the impact occurred on the windscreen the collision may have had significantly greater consequences. However, the RQ-7, at maximum gross weight 460 pounds[14], weighs significantly more than the small (20 pound or lighter) UASs which are envisioned to be operated under the new paradigm.

While a collision with any object with an aircraft that may be flying at 200 knots could be catastrophic, aircraft are designed to withstand some impact with airborne objects (see bird strike requirements)[†]. It is true that a bird is significantly more frangible than an aircraft of equal weight with motors, batteries, and sensors. A collision with a small UAS is likely to be less severe than a mid-air collision with even the smallest aircraft capable of carrying a human pilot (e.g., a 254 lbs ultralight). There are a number of documented incidents where remote control model aircraft have had mid-air collisions with a manned aircraft without a catastrophic result[‡].

Can we establish frangibility requirements for small UAS that in the event of a collision with an aircraft the consequences would be no worse than a bird strike?

Thus, risk to persons on board another aircraft can be minimized by operating a small UAS in non-navigable airspace protected by obstacles. If a failure occurs and the small UAS does encounter a manned aircraft and they do collide, the consequences of the collision could *potentially* be reduced by the small size and frangibility of the small UAS.

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[*] LIDAR: Light Detection and Ranging technology which uses pulses of light (usually laser) to measure the range to an object. This technology is fairly mature and is used in a number of safety critical applications.[11]
[†] See 14 CFR Sections 23.775; 23.1323; 25.571; 25.631; 25.775; 25.1323; 29.631; 33.76; and 35.36. These regulations govern the requirements for various aircraft components to withstand impact or ingestion of birds of varying weights from 2 lbs to 8 lbs depending upon the aircraft category and component. It should be noted that an adult Canadian Goose could weigh from 6 to 11 pounds (http://birds.audubon.org/).
[‡] See NASA's Aviation Safety Reporting System (ASRS) database reports 321899 and 222825.
See FAA's Accident/Incident Data System (AIDS) reports 20070324003409I and 19900930058519I.
See NTSB's Accident database report MIA83LA099.

Risk to Persons On the ground

In the three future scenarios presented in Section 2, it would be rather easy for the small UAS operator to ensure that access to the surface area under the operation is controlled to significantly reduce the risk to people on the ground. In addition, small UAS could be operated away from any open air assembly of people. Given the light weight of a small UAS, any people in a building or vehicle are not likely to be at risk of serious injury or death.

Not all operations can be conducted where the surface area is cleared of unsheltered, non-participants. Perhaps a frangible aircraft or an aircraft that gracefully returns to the ground in the event of a failure could reduce the risks to those on the ground (e.g., parachute).

Can design and construction standards be established that would ensure that a small UAS has a flight termination capability that reduces the risk of injury to those on the ground?

Is there really a significant risk to people on the ground beyond what is already deemed an acceptable level? There are many non-aircraft objects (e.g., baseball, golf ball) that soar in the air that could prove lethal if they struck a human. Since these are obviously not aircraft they are not regulated by the FAA. There has been some research in this area as military and law enforcement agencies explore non-lethal projectiles.[15, 16, 17, 18] There are many factors which would determine the lethality of an object striking a human including the shape and size of the object (force per area), where the object strikes the human (e.g., neck vs. legs), and the kinetic energy of the object.

Can design and construction standards be established that would enable a small UAS to be built that poises minimal risk to persons on the ground even if they are directly struck by the aircraft?

Let us look at kinetic energy. Kinetic energy is energy of an object due to its motion. It is directly related to the mass or weight of the objective. Two objects moving at the same speed that weigh different amounts will have different kinetic energy levels.

$$\textit{Kinetic Energy} = \tfrac{1}{2}\,\textit{Mass} \times \textit{Velocity}^2$$

According to long established principles, an object which impacts a human is considered likely to be lethal if its kinetic energy is greater than 80 Joules.[19] Some research by the United Kingdom Ministry of Defense into the lethality of accidental explosions produced the chart in Figure 6 which compares the probability of fatality with the kinetic energy of an object striking an unprotected human subject.[19] Table 2 summarizes the kinetic energy for two common sports objects with the kinetic energy produced by small UAS and the kinetic energy produced by remote control model aircraft which are able to operate with few restrictions today.[20, 21]

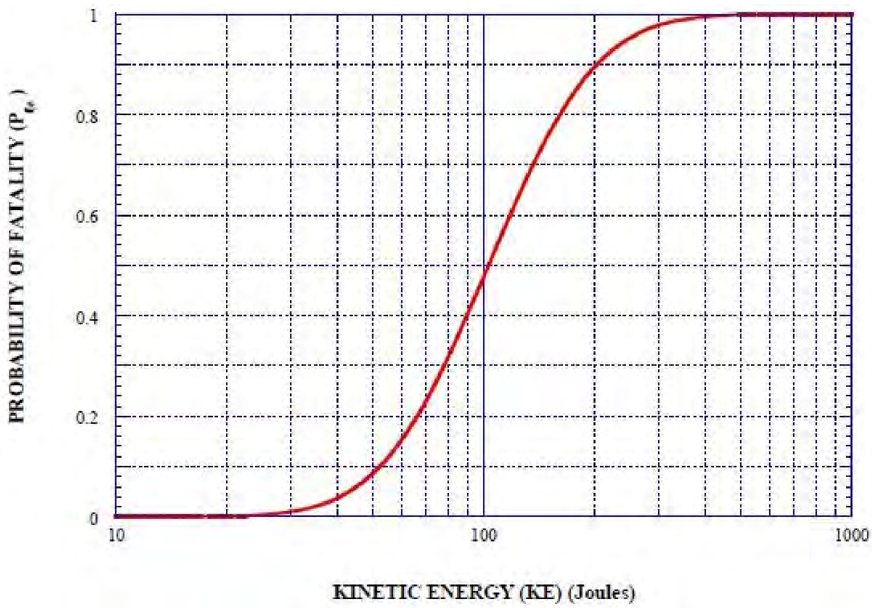

Figure 6. Kinetic Energy vs. Probability of Fatality [19]
(Henderson, UK MoD Deputy Chief Inspector Explosives)

As the reader can see from the Table 2 and the Figure 6, both the baseball and golf ball could have a kinetic energy that would be lethal over 50% of the time. At the same time a small UAS like the WASP or the DraganFlyer X4 discussed in Section 1, would produce a kinetic energy which would results in lethality 10% of the time if they hit a unprotected human at full speed (from Figure 6).

Table 2 Compares the Horizontal Kinetic Energy of a Number of Objects

	Baseball	Golfball	Very Small UAS (WASP)	Small UAS (DraganFlyer X4)	Park Flyer RC Model Aircraft	Small UAS	The Largest Model RC
Weight (lbs)	0.31	0.10	0.95	1.50	2.00	20.00	55.00
Comparision Velocity (mph)	95	170	40	35	60	25	200
Kinentic Energy (joules)	128	131	69	81	326	567	99714

The Academy of Model Aeronautics (AMA) has developed the Park Flyer Program[22] to encourage interest in the model aircraft hobby. The intent is that these aircraft can be flown safely just about anywhere. According to the data in Figure 6 and Table 2, Park Flyers at the maximum weight and speed could be lethal. Of course model aircraft can be much larger and are capable of much greater speeds.

What is the minimum kinetic energy that would lethal if a small UAS directly impacted a person on the ground?

Thus, the risks to persons on the ground can be mitigated by controlling ground access to the operational area and for very small UAS (<1.5 lbs) the risk is mitigated by the low kinetic energy of the airframe.

6. SUMMARY

Small Unmanned Aircraft Systems (UAS) are different than almost any other kind of aircraft. They can fly in places where no manned aircraft flies or would want to fly. They also pose different risks based upon their small size and performance. There are some areas in which manned aircraft are simply not capable of flying by existing Federal Regulations. This may include areas that are very close to the sides of buildings, under bridges, below tree cover, and near power cables. Our research speculates that small UAS might make use of this airspace, which would be considered non-navigable by traditional manned aircraft due to the proximity of obstacles. Additionally, a small UAS may weigh only a few ounces. An aircraft that small is likely to pose a much lower risk to people and property on the ground than would a manned aircraft. Thinking about airspace and risk in this manner represents a completely different paradigm that may influence the methods of regulating these new aircraft. In this paper we explored the potential for UAS to operate under the new paradigm and identified a number of research and policy questions that will need to be answered.

Should we take advantage of the physical and operational differences in small UAS to establish new operational paradigms, which enable them to operate in non-navigable airspace that poses an acceptable risk to both other aircraft and people on the ground?

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