

NASA/TM-2014-218253



Making the Case for New Research to Support the Integration of Small Unmanned Aircraft Systems into the National Airspace System

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April 2014

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April 2014

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Acronyms

<i>ADS-B</i>	<i>Automatic Dependent Surveillance-Broadcast</i>
ADTI	Advanced Defense Technologies Inc.
AEVA	Aerial Electric Visual Assistant
AGL	Above Ground Level
<i>AIM</i>	<i>Aeronautical Information Manual</i>
ARC	Aviation Rule-Making Committee
ATC	Air Traffic Control
ATM	Air Traffic Management
<i>ATS</i>	<i>Air Traffic Services</i>
BVR	Beyond Visual Range
CAA	Civil Aviation Authority
CASA	Australian Civil Aviation Safety Authority
CASR	Civil Aviation Safety Regulation
<i>Cdr</i>	<i>Commander</i>
COA	Certificate Of Authorization
CONOPS	Concept Of Operations
CRDA	Cooperative Research and Development Agreement
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
FLARM	Flight Alarm
ft	feet
GCS	Ground Control Station
Ghz	Gigahertz
GPS	Global Positioning System
HSI	Human System Integration
ICAO	International Civil Aviation Organization
<i>IFR</i>	<i>Instrument Flight Rules</i>
kg	kilograms
lbs	pounds
MASPS	Minimum Aviation Systems Performance Standards
<i>mph</i>	<i>miles per hour</i>
NAS	National Airspace System

NASA	National Aeronautics and Space Administration
NIEC	NAS Integration and Evaluation Capability
<i>NOTAM</i>	<i>Notice to Airmen</i>
NPRM	Notice of Proposed Rule Making
OSED	Operational Service Environment Description
<i>PIC</i>	<i>Pilot In Command</i>
RC	Radio-Controlled
ROA	Remotely Operated Aircraft
RPA	Remotely Piloted Aircraft
<i>SAR</i>	<i>Search And Rescue</i>
SC	Special Committee
SFAR	Special Federal Aviation Regulation
<i>SSR</i>	<i>Secondary Surveillance Radar</i>
sUA	Small Unmanned Aircraft
sUAS	Small Unmanned Aircraft System
UA	Unmanned Aircraft
UAPO	Unmanned Aircraft Program Office
UAS	Unmanned Aircraft Systems
UK	United Kingdom
USA	United States of America
VFR	Visual Flight Rules
VLOS	Visual Line-Of-Sight

Abstract

Due to the Presidential signing of the FAA reauthorization bill on February 14, 2012, Unmanned Aircraft Systems (UAS) are now expected to be fully integrated into the National Airspace System (NAS) by September 30, 2015, with small UAS (sUAS) becoming integrated by mid-2014. Some sUAS operations are supposed to be allowed in the Arctic regions of the U.S. (24 hours a day) at an altitude of 2,000 feet by early 2014. Although allowed in other countries, commercial sUAS and UAS operations are currently prohibited by the FAA in the United States of America. The FAA UAS CONOPS describes the requirements that will need to be met by all classes of UAS (including sUAS) when conducting Beyond Visual Range (BVR) operations. Currently, standards organizations and UAS NAS integration research are mostly focused on the operational and procedural requirements of medium and large UAS, while only the certification requirements for sUAS are being addressed. It appears that the eminent NAS integration of sUAS BVR operations and subsequent Visual Line-of-sight (VLOS) operations, some of which are scheduled to occur prior to other classes of UAS, and the research that needs to be completed to support this integration, without some form of protected airspace, has not been fully appreciated. Additionally, VLOS operations for sUAS integration have been virtually neglected in research efforts thus far.

This paper describes the current state of sUAS regulation, their technical capabilities and the latest technologies that will allow for sUAS NAS integration. The research that is needed to demonstrate sUAS NAS integration capability is identified, and recommendations for conducting this necessary research are suggested.

1 Introduction

This paper discusses several of the various small unmanned aircraft system (sUAS) operational applications that are expected to begin to take place within the National Airspace System (NAS) in the next few years. The term “unmanned aircraft system,” means an unmanned aircraft and associated elements (including communication links and the components that control the unmanned aircraft) that are required for the pilot in command to operate safely and efficiently in the national airspace system (112th Congress, 2012, §331(9)). The Federal Aviation Administration (FAA) has designated unmanned aircraft systems weighing less than 55 pounds (lbs) as small, while those weighing 55 lbs or greater are simply designated Unmanned Aircraft Systems (UAS). The two basic types of sUAS operations are categorized as being those operations which are conducted within visual sight of the sUAS pilot, or Visual Line-Of-Sight (VLOS), and those that are conducted Beyond Visual Range (BVR) of the pilot.

1.1 Purpose

The purpose of this paper is to highlight some of the advanced technical capabilities of current sUAS that can ensure the safe integration of these systems into most classes of airspace under a variety of mission scenarios. It is also intended to suggest the relevant areas of research that will provide the basis for the expeditious development of standards, guidelines and air traffic management (ATM) procedures that will harmonize these missions with other NAS operations for both VLOS and BVR operations.

1.2 Scope

The mission scenarios discussed in the following pages describe the sUAS operations that are envisioned, the environments within the NAS in which they are expected to occur, and the interactions that may take place between the Ground Control Station (GCS) pilot, Air Traffic Control (ATC) and pilots of manned aircraft. Many of these mission scenarios are expected to be conducted as BVR operations, which have already been addressed along with larger UAS operations in the FAA UAS Concept Of Operations (CONOPS) document v2.0 (U.S. Department of Transportation, 2012). However, at present, there are no FAA regulations or CONOPS regarding the commercial use of sUAS under VLOS.

In addition to the anticipated sUAS scenarios, this paper also addresses some of the regulations and requirements concerning UAS/manned aircraft integrated operations that are currently under development outside of the United States of America. It also describes the technological capabilities of sUAS vehicles and their associated GCS, as well as the technologies that will allow them to safely integrate with other NAS operations. The mission scenarios described highlight how the envisioned integrated operations are expected to occur. The scope of the work being conducted by UAS standards organizations is also discussed, as well as the specific areas where research and demonstration are currently lacking. Finally, a means to addressing this research and the need for demonstration is outlined.

2 sUAS: The Current State

Due to the Presidential signing of the FAA reauthorization bill on February 14, 2012, Unmanned Aircraft Systems are now expected to be fully integrated into the NAS by September 30, 2015, with sUAS becoming integrated by mid-2014 (112th Congress, 2012). Some sUAS operations are supposed to be allowed in the Arctic regions of the U.S. (24 hours a day) at an altitude of 2,000 feet by early 2014 (112th Congress, 2012, §332(d)(1)). Currently, standards organizations and UAS NAS Integration research that is being conducted by the National Aeronautics and Space Administration (NASA) and the

FAA are mostly focused on the operational and procedural requirements of medium and large UAS, while only the certification requirements for sUAS are being addressed. It appears that the eminent NAS integration of sUAS BVR operations, which are scheduled to occur prior to other classes of UAS, in the near-term, and the research that needs to be completed to support this integration, without some form of protected airspace, has not been fully appreciated. Additionally, VLOS operations for sUAS integration have been virtually neglected in research efforts thus far.

2.1 Background

The use of sUAS has become widespread throughout military operations over the past couple of decades because of their unique capabilities to accomplish tasks that humans on the ground and manned aircraft are unable to achieve with as great an amount of safety, effectiveness and efficiency. This has been noticed by the industry, as well as many potential public and commercial sUAS user organizations, and several extra-military applications have been envisioned and designed. Some of these applications are designed to be VLOS because their missions are local to the placement of the GCS and pilot. However, many other applications require that the pilot operate the unmanned aircraft (UA) BVR due to the nature of these envisioned missions. These missions would not make any sense if they had to conform to VLOS requirements. For instance, power-line damage following a major hurricane could be inspected effectively and efficiently using a sUAS that is guided BVR remotely from a temporary staging area to cover a section of the city. Video of storm damage could be collected at the remote GCS and streamed to the command center and utility vehicles. This would greatly increase the speed of power line repair, as utility vehicles would not be required to drive around looking for the damage. This scenario would not make sense if the sUAS pilot had to keep the UAS within VLOS. He would need to drive to the area where the damage is located during the search and would probably see it from the truck, thus making the use of a sUAS far less effective and efficient.

2.2 Current and Developing Regulations/Requirements for UAS/Manned-Aircraft Operations in the USA

2.2.1 Certificate of Authorization and Experimental Airworthiness Certificate

In the United States of America, the FAA currently allows the operation of sUAS in the NAS through the issuance of a Certificate Of Authorization (COA) for public agencies, and through the issuance of an Experimental Airworthiness Certificate for civil operations, such as research and development, crew training and market surveys. A civil aircraft is any aircraft other than a public aircraft. Public aircraft include those used by government agencies, and those leased or owned by the government and operated by any person for the purpose of crew training, equipment development, or demonstrations. Commercial use of UAS for photography or any other purpose for profit is currently forbidden.

The FAA Unmanned Aircraft Program Office (UAPO) has developed an online COA process to make application more efficient. The online application requires all UAS operators have a pilot certificate (FAA or government equivalent) under most circumstances. It also implies the pilot in command and observer both have a valid FAA Class II (or equivalent) medical certificate (Egan, 2012).

2.2.2 Notice of Proposed Rule Making

The FAA has decided to follow a model it successfully used for the integration of light sport aircraft a few years ago in its approach to the integration of sUAS into the NAS. Using this model, the FAA will issue a Notice of Proposed Rule Making (NPRM), which is currently under development through the

efforts of an Aviation Rule-Making Committee (ARC). This will be followed by development of a Special Federal Aviation Regulation (SFAR) that will allow sUAS to fly in the NAS for compensation or hire. However, the FAA will require operators to comply with rules and standards to ensure the safety of other airspace users, and persons and property on the ground. James Sizemore of the UAS Program Office (Sizemore, 2010) described the FAA's requirements concerning sUAS NAS operations in a briefing.

It is noteworthy that Sizemore's SFAR PART 107 briefing (2010) indicates that this regulation is a conservative "First Step" in introducing sUAS into the NAS. Slide #7 states that sUAS will be flown by "pilots" only in daytime Visual Flight Rules (VFR) conditions at low altitudes within "VLOS," and not over people or inhabited structures. Slide #8 states that sUAS will only have limited access to the NAS (Sizemore, 2010). What this does allow is a faster, more efficient process for obtaining a permit to operate and a certificate or authorization for personnel. However, it may not be liberal enough to allow for the BVR scenarios that are planned to take place within a very short time period, such as the Arctic flights that must be approved for BVR operations by early 2014, under the Modernization and Reform Act of 2012 (112th Congress, 2012). It also may be too restricting for many envisioned VLOS missions, in that it requires that they are to be flown by certified pilots.

2.2.3 UAS Concept of Operations

On September 28, 2012, the FAA published a document setting standards for UAS NAS integration (U.S. Department of Transportation, 2012). This document, which has become known as the FAA UAS CONOPS, addresses the integration of UAS and sUAS BVR operations into the NAS. However, it does not apply to sUAS VLOS operations. As stated before, the FAA regulations apply only to civil aircraft, so this document does not apply to public UAS operations.

The FAA UAS CONOPS lists the following general requirements and assumptions for UAS integration (U.S. Department of Transportation, 2012, p. 17):

1. UAS operators comply with existing, adapted, and/or new operating rules or procedures as a prerequisite for NAS integration.
2. Civil UAS operating in the NAS obtain an appropriate airworthiness certificate while public users retain their responsibility to determine airworthiness.
3. All UAS must file and fly an IFR (Instrument Flight Rules) flight plan.
4. All UAS are equipped with ADS-B (Automatic Dependent Surveillance-Broadcast) (Out) and transponder with altitude-encoding capability. This requirement is independent of the FAA's rulemaking for ADS-B (Out).
5. UAS meet performance and equipage requirements for the environment in which they are operating and adhere to the relevant procedures.
6. Each UAS has a flight crew appropriate to fulfill the operators' responsibilities, and includes a PIC (pilot in command). Each PIC controls only one UA.
7. Autonomous operations are not permitted. The PIC has full control, or override authority to assume control at all times during normal UAS operations.

8. Communications spectrum is available to support UAS operations.
9. No new classes or types of airspace are designated or created specifically for UAS operations.
10. FAA policy, guidelines, and automation support air traffic decision-makers on assigning priority for individual flights (or flight segments) and providing equitable access to airspace and air traffic services.
11. Air traffic separation minima in controlled airspace apply to UA.
12. ATC (air traffic control) is responsible for separation services as required by class of airspace and type of flight plan for both manned and unmanned aircraft.
13. The UAS PIC complies with all ATC instructions and uses standard phraseology per FAA Order (JO) 7110.65 and the Aeronautical Information Manual (AIM).
14. ATC has no direct link to the UA for flight control purposes.

Additionally, all UAS and sUAS (BVR operations) are required to comply with Sense and Avoid responsibility in all classes of airspace.

Although the UAS CONOPS requirements apply to sUAS BVR operations, it does not specifically address them. It simply states that the document applies to all UAS except VLOS operations. Because of the unique attributes of sUAS, there will most likely be special procedural requirements placed upon them in certain classes of airspace, and these are not addressed in the document. The fact that VLOS operations are not addressed here leaves these types of operations without a means of compliance for NAS integration. Despite these deficiencies, the FAA has made progress recently by certifying two types of sUAS (Insitu's Scan Eagle and AeroVironment's PUMA) for civilian use. AAP reports that, "A major oil company plans to fly the Scan Eagle off the Alaska coast starting in August to survey ice floats and migrating whales. The Puma is expected to support emergency response crews for oil spill monitoring and wildlife surveillance over the Beaufort Sea" (AAP, 2013).

2.3 Current and Developing Regulations/Requirements for UAS/Manned-Aircraft Operations Outside the USA

2.3.1 *Australia*

The Australian Civil Aviation Safety Authority (CASA) is a world leader in UAS operations having published the world's first operational regulation in 2002, Civil Aviation Safety Regulation (CASR) Part 101, "Unmanned Aircraft and Rocket Operations" (Civil Aviation Safety Authority, 2002b). In 2009, the Australian Government stated its intention to ensure that CASA would enhance its oversight of the operation of UAS, leading to a corporate plan that contains the objective of strengthening CASA's specialist surveillance staff to oversee the operation of UAS, as well as a UAS specialist position to deal with the operational aspects of UAS.

The current regulations, developed in 2002, provide the framework within which all classes of UAS can be operated in Australian airspace. An Advisory Circular (AC) 101-1 "Unmanned Aerial Vehicle Operations, Design Specifications, Maintenance and Training of Human Resources" provides detailed support of these regulations (Civil Aviation Safety Authority, 2002a).

Under these regulations, CASA has had to treat every application for the operation of Remotely Operated Aircraft (ROA) as a standalone exercise, which requires significant education of applicants and a high probability of inconsistent responses, which may be considered a safety risk. The regulatory interest has primarily been concentrated on the large class of ROA; however, a growing number of manufacturers and operators of small and medium size ROAs have been supporting commercial operations that require attention. According to James Coyne (n.d.) of the Civil Aviation Safety Authority-Australia, the types of ROA operations which are currently active in Australia include (p. 6):

- Aerial Photography
- Noxious weed identification and eradication
- Vegetation Monitoring
- Fire Fighting Support
- Pollution Monitoring
- Mine Site Surveys
- Electricity power line and pole surveys
- Law Enforcement
- Crop spraying
- Feral animal tracking
- Location and eradication of harmful introduced species of insects.

According to James Coyne (2011, pp. 106-107), new regulations to replace CASR Part 101-1 are undergoing Post Implementation Review this year and new regulations will be drafted by next year. Under consideration is a change from using 150 kilograms to designate the small category to that of using kinetic energy for classification. Meanwhile, AC 101-1 is being rewritten to harmonize with the work of International Civil Aviation Organization (ICAO) and other regulatory bodies, replacing the term Unmanned Aerial Vehicle with the terms Unmanned Aircraft System (UAS) and Remotely Piloted Aircraft (RPA). The final AC 101-1 will be re-titled, “Unmanned Aircraft Systems – Operations, Design Specification, Maintenance and Training,” providing guidance to operators, remote pilots, manufacturers and maintainers of UAS concerning how they may safely and legally operate them.

Recently, CASA proposed a new set of rules that would divide all commercial drones into four categories, based upon weight and kinetic energy. The smallest (weighing 2 kilograms or less) would be allowed to legally fly after simply completing an online application form. The Australian Broadcasting Commission reports, “From sport to news gathering to lifesaving patrols, there are dozens of potential civilian applications of drone technology. Currently there are just 33 CASA-approved commercial drone operators in Australia, mainly deployed on scientific research, surveying and aerial photography” (Corcoran, 2013). The proposed rules, if passed, would allow hundreds of small commercial drones to legally take to the skies.

2.3.2 Canada

Canadian liability insurance and a permit from Transport Canada are required for commercial unmanned aerial photography activities. A permit is necessary for each job and each permit takes approximately four weeks to obtain. Transport Canada lists the following information on their website (Government of Canada, 2012):

How unmanned air vehicles are different from model aircraft

"Model aircraft" means an aircraft, the total weight of which does not exceed **35 kg** (77.2 pounds), that is mechanically driven or launched into flight for **recreational purposes** and that is not designed to carry persons or other living creatures. Although some micro unmanned air vehicles may weigh less than 35 kg, they are operated by research institutions and other organizations for non-recreational purposes.

How unmanned air vehicles are regulated

Section 602.41 of the CARs states, no person shall operate an unmanned air vehicle in flight except in accordance with a Special Flight Operation Certificate (SFOC). Section 623.65 outlines information that should be submitted when making an application for a SFOC. ... You must be able to demonstrate the predictability and reliability of the unmanned air vehicle, essentially that it has the ability to perform in the desired environment.

Definition of Unmanned Air Vehicle (UAV)

Section 101.01 of the Canadian Aviation Regulations (CARs) states, "Unmanned Air Vehicle" means a power driven aircraft, other than a model aircraft, that is operated without a flight crew member on board.

How unmanned air vehicles are regulated

The following constitutes an application to conduct the flight of an unmanned air vehicle:

- ...
- (d) the type and purpose of the operation;
- ...
- (f) a complete description, including all pertinent flight data on the aircraft to be flown;
- (g) the security plan for the area(s) of operation and security plan for the area(s) to be overflown to ensure no hazard is created to persons or property on the surface;
- (h) the emergency contingency plan to deal with any disaster resulting from the operation;
- ...
- (j) a detailed plan describing how the operation shall be carried out. The plan shall include a clear, legible presentation of the area to be used during the operation. The presentation may be in the form of a scale diagram, aerial photograph or large scale topographical chart ...

Unmanned Air Vehicles Operating Beyond Visual Range

More and more UAV operators are making applications for Special Flight Operations Certificates (SFOCs) where the UAV is to be operated beyond visual range. Once the applicant demonstrates the ability to conduct a safe operation, the Minister shall issue the special flight operations certificate.

Detect, sense-and-avoid (DSA) capability is a key to routine UAV operations. ... [A] DSA system will have to detect the traffic in time to process the sensor information, determine if a conflict exists, and execute a manoeuvre according to the right-of-way rules. If pilot interaction

with the system is required, transmission and decision time must also be included in the total time between initial detection and the point of minimum separation. The DSA system will have to possess the capability to detect both participating and non-participating aircraft.

The probability of a UAV colliding with another aircraft must be comparable to that for manned aircraft (i.e. an equivalent level of safety).

Although civil use of drones in the U.S.A. is still on the horizon, Canada is already allowing their use. For example, Public Radio International reports, “To the north, Canada is moving ahead more quickly. You can get a permit to fly a UAV in a matter of weeks through the Transport Canada agency. But even with that license, which is handled on a case-by-case basis, you can’t fly a UAV higher than 400 feet” (PRI’s The World, 2013).

2.3.3 India

In India, a permit for commercial aerial photography is required (reel india pictures, 2007-2008), taking at least one month to obtain. Regulations apply to photography in certain locations. A projection was recently made by Advanced Defense Technologies Inc. (ADTI), which indicates that India will become a booming market for micro- and mini-unmanned aerial vehicles for both civilian and military use. According to R.S. Tahim, president and chief executive officer of ADTI, “The general public will soon understand that less controversial uses for UAVs are being explored increasingly in the humanitarian, environment and agricultural sectors. In many cases, the systems are safer and cheaper than manned aircraft and in some cases the mini- and micro-drones will do things for the commercial civilian markets that were not possible before” (UPI, 2013).

2.3.4 Europe

In Europe, EC Regulation 1592/2002 (the EASA Regulation) has established the European Aviation Safety Agency and makes provision for implementation rules concerning airworthiness certification (European Parliament and Council, 2002). These rules do not apply to state aircraft engaged in military, customs, police or similar activities. Civil aircraft that are exempt from these rules are listed in Annex II to EASA. These include:

- Aircraft specifically designed or modified for research, experimental or scientific purposes and likely to be produced in very limited numbers
- Aircraft whose initial design was intended for military purposes only
- Unmanned aircraft with an operating mass of less than 150 kg.

2.3.5 United Kingdom

In the United Kingdom (UK), there are only two regulatory regimes: civil and military. There are no special provisions for aircraft used by police, customs, or other similar services. Any aircraft not designated as military by the Ministry of Defense must comply with civil requirements. Any non-military aircraft weighing more than 20 kilograms (kg) not covered by the EASA Regulation and Implementing Rules must have a certificate of airworthiness or a permit to fly issued by the UK Civil Aviation Authority (CAA). Small unmanned aircraft (sUA) weighing no more than 20 kg must operate outside controlled airspace at an altitude of no more than 400 feet (ft) above ground level (AGL), unless permission is granted by air traffic control (United Kingdom, 2012).

CAP 722 is the UK Civil Aviation Authority's Guidelines on the use of unmanned aircraft within UK controlled airspace (United Kingdom, 2012). The 4th edition of CAP 722 was published April 2010, introducing new regulations concerning air navigation. This document is intended to aid the industry in identifying the route to certification, and to highlight the safety requirements that have to be met for airworthiness and operational standards. Currently, UAVs are restricted to segregated airspace for their operations. The goal is to develop a regulatory framework which will enable full integration of UAS activities with manned aircraft throughout UK airspace. In order for UAS to operate in non-segregated airspace in the UK, they must comply with the following requirements listed in CAP 722 (United Kingdom, 2012, §2 Chapter1 pp. 2-3):

6 General Principles for Unmanned Aircraft Operations Outside Segregated Airspace

6.1 For all flights outside Danger Areas or segregated (exclusive use) airspace, the aircraft performance and all communications with the ATS [Air Traffic Services] provider must be continuously monitored by the UAS Cdr [Commander] and/or its pilot. To comply with ATS instructions in a timescale comparable with that of a manned aircraft, it is imperative that the capability of taking immediate active control of the aircraft exists at all times.

6.2 Special equipment (e.g. Secondary Surveillance Radar (SSR) Transponder) mandated for manned aircraft in certain classifications of airspace shall also be mandated as a minimum requirement for UAS intending to fly in such airspace.

6.3 Detect and Avoid

6.3.1 An approved method of aerial collision avoidance is required and, therefore, UAS operations will not be permitted in the United Kingdom in non-segregated airspace, outside the direct unaided visual line-of-sight of the pilot, without an acceptable Detect and Avoid system. Details on how Detect and Avoid criteria may be arrived at can be found at Section 2, Chapter 2.

6.3.2 In the absence of an approved Detect and Avoid system, UAS operations outside segregated airspace are to be constrained as detailed at paragraph 6.7.

6.4 An approved method of assuring terrain clearance is required.

6.5 Standard Operating Procedures are required; these would normally be contained within an organisation's UAS Operations Manual. Amongst other things the following procedures should be covered:

- Take-off and landing procedures;
- En-route procedures;
- Loss of control data link; and
- Abort procedures following critical system failure.

6.6 UAS must comply with the Instrument or Visual Flight Rules (IFR or VFR) as they affect manned aircraft.

6.7 If the System does not have an approved Detect and Avoid capability, the restrictions detailed below will normally be applied to UAS operations outside segregated airspace as part of the CAA permissions and exemptions process. The aircraft shall not be flown:

- in controlled airspace, except with the permission of the appropriate ATC unit;

- in any aerodrome traffic zone except with the permission of either the appropriate ATC unit or the person in charge of the aerodrome;
- at a height exceeding 400 feet above the surface;
- at a distance beyond the visual range of the Remote Pilot/RPA observer of the said aircraft, or a maximum range of 500 metres, whichever is less;
- over or within 150 metres of any congested area of a city, town or settlement; or
- within 50 metres of any person, vessel, vehicle or structure not under the control of the Remote Pilot; during take-off or landing, however, the aircraft must not be flown within 30 metres of any person, unless that person is under the control of the Remote Pilot.

Civil use of drones has been increasing in the UK. According to *BBC News Technology*, “the UK’s airspace regulator, the Civil Aviation Authority (CAA), has told BBC Newsnight that large unmanned drones could be flying in British skies by the end of the decade. The CAA has already handed out 120 permits to fly small, lightweight drones. By 2020 this may be extended to the larger unmanned aircraft” (Reed, 2012). Also, according to a research project backed by the UK government and top aerospace companies, “military drone technology, which has revolutionized warfare over the last decade, will be ready for civilian use within four years and could create a market worth more than \$400 billion” (Wickham, 2012).

2.3.6 Italy

The Italian Civil Aviation Authority has granted its first permit to fly a sUAS in non-segregated airspace (Carey, 2012). The permit was granted October 30, 2012 to AERMATICA for its UAV ANTOS. The ANTOS platform will be used in many applications for industry, academia and business-commercial. The first authorized UAV flight in an urban environment in Italy will be conducted with the ANTOS to elaborate upon and to update a data base about the status of the Basilica S.M. di Collemaggio in L’Aquila, Italy. The Basilica was damaged by an earlier earthquake. The data will be used to properly plan any eventual structural interventions when needed. The sUAV flights will be conducted to create three-dimensional models of both the building and its roofs using photogrammetric dedicated techniques. sUAS News further explains that “all survey data will therefore be used to create a database with metric and cartographic qualities. This database will be interrogated using ad-Hoc created algorithms and queries under GIS (Geographic Information System) applications in order to disseminate already elaborated data with web-GIS platforms. Moreover integrating optical and thermal sensors also a georeferenced thermal model containing structural information will be created and divulged under the same GIS applications” (Mortimer, 2013).

2.3.7 Mexico

According to the Missouri Drone Journalism Program, “no Civil Aviation Authority regulations beset UAV users in Mexico. In fact, Mexican attitudes evidently encourage UAV use. The Mexican government rewarded Jordi Muñoz, who is a young scientist and engineer, for exploring the peaceful uses of drones through his own production company, for example. The government also uses UAVs for everything from drug activity to university research” (Garcia, 2013).

2.3.8 Brazil

Zach Garcia of The Missouri Drone Journalism Program also states that “in South America, Brazil has become a leading player in UAV use. On the national level, the country is investing deeply in UAVs to

patrol its borders. There are also no direct laws that infringe free civilian use” (Garcia, 2013).

2.3.9 Peru

As with some other countries in South and Central America, “There are no laws in Peru regulating the civilian use of drones, which allows advocates to push for all kinds of projects” (AFP, 2013). Drones used here are small-size, hand-held devices that look like they were assembled from off-the-shelf hardware. “They are equipped with a microcomputer, a GPS [Global Positioning System] tracker, a compass and an altimeter, and can be easily programmed by using Google Maps to fly autonomously and return to base with vital data... They are equipped with high-precision video or photo cameras and go virtually unnoticed in the sky...” They have been used “for agricultural purposes, where they gather information on the health of the plants, and in archeology, to better understand the characteristics of each site and their extensions...” In agriculture drones allow observation “of a larger cultivation area to estimate the health of the plants and the growth of the crops. The cameras aboard drones provide ... 500 pieces of high-technology data, while with the human eye one can barely collect ten. Precise, high quality images allow experts to measure the amount of sunlight the plants are getting, and study plant problems like stress from heat, drought or lack of nutrients” (AFP, 2013).

2.3.10 Asia

In Asia “both communist China and democratic Japan are using UAVs to square off with each other in a sort of micro-aggressive battle for disputed land. Similarly, South Korea also may be dipping its toes in militaristic UAV use through possible collaboration with the U.S. The only non-military use of UAVs that we’ve been able dig up [sic] in the region are limited to corners of agriculture, such as with rice fields of Japan” (Garcia, 2013).

2.3.11 New Zealand

According to Zach Garcia of the Missouri Drone Journalism Program, “New Zealand law is like Australia, but without the identification requirement. It appears as if recreational and commercial motivations for UAV flight are indistinguishable in New Zealand. The Aviation Industry Association of New Zealand has proposed legislation on UAVs, but the proposal is reportedly more of a non-restrictive manual for UAV use than anything” (Garcia, 2013).

2.4 sUAS Vehicle/GCS Capabilities

Many GCS configurations have been developed by the military to satisfy various mission requirements. The UAS manufacturers have begun to build upon these designs to further develop GCS technologies that will be compatible with civilian and public sUAS mission requirements. The following are a few examples described by some of these manufacturers. In all cases, these GCS capabilities for both large and small UAS are quickly surpassing the proposed FAA rules.

2.4.1 New Legacy RC Controllers with Telemetry

RC (Radio-Controlled) manufacturers have developed controllers with telemetry. The new 2.4 Gigahertz (Ghz) transmitters monitor receiver status and frequency hopping allows a channel for information to come back to the pilot. Some of these controllers have a GPS add-on, which will provide information on heading and groundspeed. All of the units have sliders and switches built in that can be used for camera pan and tilt, and for triggering return home action with the autopilot. Controllers can be

integrated with the OpenPilot autopilot and its Pipbee modem, which addresses the problem of weight in sUAS (Mortimer, 2010).

2.4.2 CRESCENT BRAVO 300 sUAS GCS

According to the online brochure (Crescent Unmanned Systems, n.d.), their ground control station's "advanced capabilities such as Auto Take off and landing, waypoint acquisition, altitude and position hold, ensure ease of operation." It describes three attributes of their GCS in more detail:

SEMI AUTONOMOUS FLIGHT

Virtual Cockpit 3D allows an operator to stay focused on the mission at hand. Autonomous Take off and Landing, Waypoint Navigation, and click to fly operability make the Bravo 300 exceptionally easy to operate. Altitude and position hold are rock solid in sustained winds up to 30mph [miles per hour].

MULTIPLE ASSET CONTROL FROM USER INTERFACE

The ability to control multiple air assets in a search and rescue operation could mean the difference between life or death for those in need of rescue. A single operator can control up to 5 units from the same screen ensuring maximum coverage of search areas.

TARGET ACQUISITION AND TRACKING

Whether it's convoy protection, or tracking a fleeing suspect, target acquisition and tracking is an invaluable asset that allows you to follow a designated target.

2.4.3 BROCK Technologies

Brock Technologies, Inc. of Tucson, Arizona has developed a versatile and innovative handheld GCS known as the Micro Portable Ground Control Station (uPGCS). "With the added flexibility to use the system as a standalone video receiver, or pass control of a UAS from one uPGCS to another, the handheld device can be used by many mission participants in the field enabling mass dissemination of data and increasing the operational range of UAS utilizing a Piccolo autopilot" (Brock Technologies, n.d.).

2.4.4 Lockheed Martin

The online capabilities guide describes Lockheed Martin's Vehicle Control Station 4586 (VCS-4586) as "an integrated command, control and information system designed for controlling and monitoring unmanned vehicle systems. It is the world's first commercial off-the-shelf (COTS) control station software developed in accordance to STANAG 4586. VCS-4586 allows operators to simultaneously control multiple vehicles of varying types from a single workstation and common user-interface" (Lockheed Martin, n.d.).

2.4.5 Communis Tech

Communis Tech will soon be releasing the first version of MAVPilot. "This is a 'Ground Control Station for your Pocket'. Its target audience is iPhone users (iPad version will come later). With inbuilt text-to-speech support your iPhone will let you know instantly the status and if anything starts to go wrong" (Cummunis Tech, 2013).

2.4.6 UAV Factory

UAV Factory has developed reconfigurable, suitcase-sized portable Ground Control Station (GCS) “designed for controlling unmanned vehicles. By using a unique, modular electronics compartment (MEC), application specific hardware can be quickly installed. This flexibility allows the GCS to be configured to control unmanned aircraft vehicles (UAV), ground robots, bomb disposal robots, remotely operated vehicles (ROV) and other robotic devices. The GCS can also be configured to control and monitor measurement and sensing equipment” (UAV Factory, n.d.).

2.4.7 Olaeris Domesticated UAS for Fire, Police and Rescue Agencies

Aerial Electric Visual Assistant (AEVA™) is an autonomous, robotic system that is supervised by a remote human pilot (Dallas Press, 2012):

A new VTOL (Vertical Takeoff and Landing) Unmanned Aerial System (UAS) named AEVA™ ... has been specifically developed for domestic emergency responders including fire, police and rescue workers. AEVA™ uses robotic intelligence to analyze her surroundings and change direction automatically, making her safer to operate over populated areas. AEVA™ can sense and avoid other aircraft and at lower altitudes, can identify obstacles such as trees, buildings and people. Onboard processors analyze sensor data and adjust the flight path automatically to avoid collision.

2.5 sUAS NAS-Integration Technologies

In recent years there have been many technologies developed which will enable sUAS to be integrated into the NAS. These technologies allow the sUAS to broadcast its position and to sense the position of other aircraft in its vicinity. These new technologies are continuously being improved upon, and the following are some examples of what manufacturers have developed to date.

2.5.1 FLARM

In Norway, a non-profit, dependent national UAS organization was established in 2008. Per Olsen (2011) published an article on behalf of this organization titled “Beyond Line-of-Sight UAS Operations Should Be Taken Into Account NOW.” The article describes a low-cost, light-weight sense-and-avoid technology developed for gliders and general aviation that could be adapted for use by sUAS. The technology is called FLARM (Flight Alarm). The article suggests that non-certified equipment such as FLARM is currently being approved for sUAS BVR operations on a case by case risk analysis by the Norwegian CAA, and that these operations are being safely conducted.

2.5.2 Sagetech Small ADS-B/Mode S Transponder

Sagetech has developed the XPS-TR Transponder, which includes both a Mode S transponder and ADS-B in and out capability (Mortimer, 2012). The unit weighs less than a cell phone with a size comparable to a business card. This allows the sUAS pilot the capability of detecting aircraft within the vicinity of the sUA, while also broadcasting its position to radar controllers and other ADS-B equipped aircraft.

2.5.3 *Lost-Link Procedure Technologies*

Today's autopilot technologies for sUAS allow for fail-safe strategies to address the possibility of lost communications between the pilot and the vehicle. When the autopilot senses that a lost-link has occurred, it can activate a fail-safe procedure that has been programmed by the pilot prior to departure. Possible fail-safes may activate a flight path that will direct the vehicle to directly return home or to another loitering point, where an attempt may be made to reestablish the communications link. The autopilot may also be directed to complete the mission flight path prior to navigation to a fail-safe point. Taking advantage of this capability, technologies that can immediately transmit this fail-safe flight plan directly to controllers upon their activation should be developed, so that ATC will be able to maintain predictability of sUAS during lost-link situations.

2.6 Mission Scenarios

The following list of scenarios have been developed and described by standards organizations, industry and other user groups. They outline a great variety of sUAS missions that can be accomplished effectively, efficiently and safely.

2.6.1 *sUAS Scenarios Described on the RTCA SC-203 UAS Committee Workspace*

The following scenarios (§2.6.1.1 through §2.6.1.8) have been acquired from the RTCA SC-203 workspace (RTCA SC-203, 2010). These scenarios were developed by committee members as guidance material to be cited as representative samples of sUAS missions that are envisioned to take place in the near future. As with the sUAS vehicle and GCS capabilities, these proposed missions surpass what would be allowed under the proposed FAA rules.

2.6.1.1 *Law Enforcement – Small, Electrically-Powered Fixed Wing (Raven) in Class B Airspace, BVR Operations.*

This scenario describes the application of a small, hand-launched Raven UA to support a police operation in the Los Angeles area. In this scenario, police in Los Angeles area are called to investigate a suspect car observed leaving a crime scene. The car was last seen near Culver City heading toward the on ramp southbound on 405 San Diego Freeway. Officers in a UAS Air Unit cruiser inform dispatchers that they will launch their UA to begin assisting in the search.

Because the operation will be flown in the Class B airspace of LAX, the pilot contacts ATC for flight clearance while the support officer unloads and prepares the aircraft for launch. Once ATC approval is given the aircraft is thrown into the air by the support officer while the pilot remains in the cruiser and directs the aircraft to the suspect car's likely location on the 405 Freeway.

Upon reaching the 405 Freeway at 400 feet AGL, the UA increases its speed to 45 knots and locates and tracks the suspect car's movement. Once positively identified, the UAS follows the car until it is apprehended by the police. The aircraft then returns to and is recovered in Culver City at the location of the UAS cruiser. The flight takes place in the early evening. Marginal visibility and light winds exist. Ocean fog is present. SMO and LAX are reporting visibility less than VFR.

2.6.1.2 Marine Monitoring – Small, Fixed-Wing Reciprocating (ScanEagle) in Class E DVFR Airspace/Air Defense Identification Zone (ADIZ)/Warning Area, BVR Operations

This scenario describes a marine fisheries protection and monitoring operation by the Department of Interior in the Dry Tortugas Marine Sanctuary. The Dry Tortugas National Park is situated within the Warning Area W-174B and the Tortugas MOA. A DOI patrol vessel (ship) stationed at Key West Naval Air-Station Boca Chica (NQX) is responsible for monitoring operations in an area approximately 100 NM radius from NQX.

The DOI patrol vessel, named “Seeker,” has an operational range of many days; however because of the age and condition of the vessel, it can only transit at 12 knots and “dash” for a short period of time (1 hour) at 18 knots. The 200 feet “Seeker” is equipped with a ScanEagle UAS and the requisite launch and recovery equipment. The control station is incorporated into the command and control center on the vessel’s bridge. The patrol vessel has a full support crew on-board to launch, operate and recover the UA, as well as carry out maintenance needed during their period of operations.

In this scenario there has been a reported sighting of an unlicensed and unknown “fishing vessel”, possibly fishing illegally and anchoring within the Dry Tortugas National Park. The DOI vessel “Seeker” has been tasked to investigate and take the appropriate action. The UA is flown to an area where the suspect vessel was last reported, performs a search pattern, and then tracks its movement when found. The flight takes place in Class E airspace and is operated under DVFR due to its crossing the US and Cuban ADIZ. The weather is marginal with low forming clouds and thunderstorms in the area. Coordination with ATC is required due to operations within a Warning Area where the UA must transit. Areas of interest in this scenario include use of a low visibility aircraft, Class E DVFR operations, crossing into and out of an ADIZ, unique launch and recovery methods, planned search pattern areas follow [sic] by random tracking of a vessel, coordination with ATC, VFR cloud clearance, and separation with observed local VFR traffic.

2.6.1.3 Puma/Wasp/RAVEN – Civil/Commercial in Controlled and Uncontrolled Airspace, BVR or VLOS Operations

Depending on flight mode selected, the UAV will either fly to the first in a series of pre-programmed waypoints, or will be manually directed by the Pilot to maneuver to and around the objective. Typical missions could include: incident and site surveillance (fire, flood, other natural disasters), police/government missions (hostage situations, Border Patrol), perimeter security (commercial, ranching) and others. After completing the objective or flying for maximum time, the air vehicle returns to the Home location or flies to a pre-programmed landing site and is directed to AutoLand.

2.6.1.4 Mini UAV – Civil/Commercial in Controlled and Uncontrolled Airspace, VLOS Operations

“Mini UAV” flight operations conducted via line-of-sight radio control system for measurements pertaining to Earth science, environmental monitoring, agricultural assessment, etc. Flights may be coordinated with nearest airport traffic controllers by telephone or radio. “See and Avoid” is accomplished by second observer relaying verbal information regarding other traffic to vehicle operator. Some level of autonomy may be used for way point navigation.

2.6.1.5 *sUAV – Atmospheric Research in Controlled and Uncontrolled Airspace, BVR Operations*

Small UAVs/UASs can be helpful for atmospheric measurements from the surface to the stratosphere. Recent developments in instrumentation will make these measurements with small vehicle systems operating primarily in an autonomous mode. “See/Sense and Avoid” may be accomplished with the use of a ground-based radar for traffic observation, combined with real-time GPS-based position information. Navigation would be by way-point with varying altitude inputs, based on measurement results and other traffic. Flight into clouds and severe weather may be desired for research purposes. Launch and recovery would be accomplished using a small runway.

2.6.1.6 *sUAS – Mass Casualty Analysis with Certificate Of Authorization (COA), BVR or VLOS Operations*

The USAF, Fish & Wildlife, as well as State response teams are dispatched shortly after a hurricane in South Florida to provide an initial assessment of damage and provide search and rescue if needed. The request to search the hundreds of square miles of the everglades by small UAVs in search of survivors would immensely aid the disaster relief effort, rescue operations, and Fish & Game wildlife officials.

As search and rescue (SAR) forces gear up for their impending task they are going over their pre-flight procedures for launching a small Unmanned Aerial Vehicle (UAV). Due to limited aircraft and weather restrictions their recovery efforts and search patterns are greatly enhanced with the use of these small hand-held UAV's. The SAR teams are equipped with small UAV's, which weigh around 4.2 pounds and are electrically powered. Operating at speeds of 30 –60 mph the UAV is capable of staying aloft for about 50 minutes. The typical operating altitude is between 150 feet up to 1000 feet AGL with a max altitude of 10,000 feet. The vehicle is designed for autonomous operations as well as manual operations; operators require one week of initial training to obtain the required skills to fly the UAV.

Upon arrival in the vicinity of the disaster the SAR forces rapidly deploy the small UAV and start mapping out areas in a grid pattern and conduct sector searches to enhance the search and recovery process. The small UAV does not have a transponder on board or any see and avoid equipment. SAR forces immediately complete a COA to develop an operating area (e.g. 5 statute mile radius from a GPS lat/long reference point, surface to 1000 feet) and forward it to FAA officials for coordination. SAR forces coordinate with local ATC and NOTAMS [Notice to Airmen] are placed to ensure that other manned aircraft are aware of the small UAV's. Additionally the SAR forces monitored the local ATC frequencies with portable radios (in case of an emergency or other requirement the UAV operators can adjust the flight path or have the UAV return to home). The use of the UAVs' day and night video capability provides the SAR forces with a real time view of the situation. It provides the analysis of survivor's situation, determining safe avenues of approach for rescue efforts, and prioritizing the urgency for response saving the SAR forces time and energy.

Because the disaster area is remote and the altitude of the UAV is low there is minimal effect on air traffic operations. However, due to the unpredictable nature of natural disasters, immediate coordination with the FAA is imperative.

2.6.1.7 *sUAS – Avalanche Survivor Searches with Certificate Of Authorization (COA), BVR Operations*

A mountain rescue team is dispatched [sic] to a remote region of a ski resort where several hikers and skiers are caught in an avalanche. The rescue team has to respond immediately because often times the victims have a limited air supply (10-20 minutes) before suffocation sets in, the most common cause of death for this type of disaster. A skier with a cell phone who witnessed the accident alerted the ski resort that in turn notified the mountain rescue team. With the information from the witness the rescue team has a general idea of the location of the incident. They are about five miles from the location and time is against them as they prep to leave for the site.

Due to manned aircraft response time of 30 minutes or more, the team relies heavily on the small UAV to aid in their search and recovery efforts. The UAV's weigh around 4.2 pounds, are electrically powered, and are equipped with ultra-sound devices. Operating at speeds of 30 –60 mph the UAV is capable of staying aloft for about 50 minutes. The typical operating altitude is between 150 feet up to 1000 feet AGL however; they can be flown lower when the situation dictates. The vehicle is designed for manual operations as well as autonomous operations; operators require one week of initial training to obtain the required skills to fly the UAV.

Upon notice of the avalanche the SAR team quickly launches the small UAV from their location, as other team members launch on snowmobiles to the site. Once the UAV is launched the pilot and mission controller depart their location for the avalanche site on their snowmobile with a mounted ground control station. The small UAV does not have a transponder or any see and avoid equipment on board. SAR forces have completed a COA that develops an operating area (e.g. 5 statute mile radius from a GPS lat/long reference point, surface to 1000 feet). Due to the nature of the emergency mission, the UAV operator will request immediate FAA approval of the COA. SAR forces will coordinate with local ATC to have NOTAMS published to ensure that other manned aircraft are aware of the small UAV's. The use of low-level UAVs saves the rescue teams precious time in pinpointing the location and providing a critical assessment of the avalanche surroundings. Using the video link and GPS coordinates of the UAV, the SAR team can provide a safe avenue of approach and avoid potential life threatening unstable areas of the avalanche site. While the SAR team is approaching the location, the UAVs carrying ultra-sound devices can pinpoint humans several feet buried beneath the snow and ice and pass back coordinates to the team. Due to the obvious, urgency in reaching these victims in a minimal time frame is one of the greatest priorities for SAR teams. Locating a survivor with the aid of the UAVs differentiates between treating a medical malady, over the archaic and traditional measures, which often times produces a recovery instead of a rescue.

Because the avalanche site is remote and the altitude of the UAV is low there is minimal effect on air traffic operations. However, due to the unpredictable nature of avalanches, immediate coordination with the FAA is imperative.

2.6.1.8 *sUAS – Aerial Imaging sUAS Helicopter in Controlled and Uncontrolled Airspace, BVR or VLOS Operations*

The Autocopter is a small industrial helicopter with a 15 pound payload capacity. The machine flies autonomously and its movements are directed by the operator. The Autocopter is being adopted by industries seeking an affordable alternative to full scale aircraft. Most owners, government agencies and commercial interest, are using the machine for aerial imaging.

After it has been determined that an area is safe for a flight, coordinating with air-traffic control where necessary, the helicopter is unloaded and placed into position. With all pre-flight safety checks passed, and cleared for takeoff, the Autocopter is ready for flight. The helicopter is started in manual mode. Radio controlled, the engine is idled up to the governor. The autopilot is engaged. The helicopter is commanded to lift off. When the desired altitude is achieved the operator moves the controls to the neutral position. With the controls in the neutral position the Autocopter will hold its position and await the next command. The helicopter may also be commanded to fly in horizontal mode, forward, backwards, and side to side. When the mission is accomplished the Autocopter is commanded to descend, until the skids touch down and the engine is killed.

The Autocopter can also be pre-programmed to fly a set waypoint pattern. After the pre-flight sequence, the Autocopter receives its commands. The engine is started, the Autopilot is engaged and the copter lifts off and flies its predetermined grid. With its mission accomplished the Autocopter returns home and lands, autonomously. The operator may, at any time, interrupt the pre-programmed flight with new commands.

If the operator's radio transmission is interrupted, the Autocopter will hold a static position until it reacquires a signal. If the Autocopter does not receive a signal for 10 seconds it enters "return home mode", retraces its path home and lands. If the engine fails, the helicopter can auto-rotate. If the blades fail, a parachute can be deployed.

2.6.2 Police Applications of sUAS in Controlled and Uncontrolled Airspace, BVR or VLOS Operations

According to Al Frazier (2013), an assistant professor at the University of North Dakota and part time Grand Forks County sheriff's deputy, specially trained police officers would carry a drone (sUAS) in a suitcase-like container as a constant companion, not unlike the current K-9 units which employ the use of police dogs. Drones would be integrated into normal patrol operations.

The officer could use the camera- or video-equipped drone as an assistant for several types of police activities (Vogel, 2012):

- As an aid in the foot pursuit of a suspect to search a field or neighborhood from above
- To survey the damage caused by a major traffic accident and use the footage to recreate how the accident happened
- For surveillance while serving search warrants and to gather information on possible entry points and escape routes, as well as to detect present hazards (such as a guard dog in the yard) or a suspect fleeing out the back door
- As a stand-in second or backup patrol officer in areas with minimal police coverage
- For alarm calls on businesses at night to view the roof of the building for possible break-in points

Another police scenario that has been described concerns the use of police drones to find and track suspects such as bank robbers (or other "runners") fleeing in automobiles. This type of scenario would reduce the hazards that are encountered during high-speed police chases that encourage suspects to drive recklessly (Gunderson, 2013).

Other police departments are already beginning to get approval for the use of sUAS. "The Mesa County Sheriff's Office in Colorado is one of the first U.S. police departments to receive FAA permission

to use UAVs. This covers a small Dragonflyer X6 hexacopter and a hand-launched Falcon UAV that can fly for an hour and fit in the trunk of a patrol car. Primary use is search-and-rescue and crime-scene reconstruction – at an operating cost of less than \$4 per hr. In more than four years of operations, the aircraft have been used for missions as diverse as locating hot spots after a church fire, surveying landfills, finding the body of a missing woman and locating hikers who had become lost” (Warwick, 2013).

2.6.3 Multiple Mission Scenarios Including Inspection and Surveillance Uses of sUAS in Controlled and Uncontrolled Airspace, BVR or VLOS Operations

There are many private and public missions that sUAS can be used for to improve effectiveness and efficiency of operations over current capabilities. Drones that are equipped with visual and/or infrared video cameras and sensors, such as radiation detectors, could perform many functions:

- Evaluate storm damage of electric utilities and determine location of possible victims
- Inspect pipelines for possible damage
- Inspect nuclear power plants for leaking radiation or power-line damage
- Act as autonomous sentries to protect private property or secure areas from intruders
- Detect nuclear devices, such as “dirty bombs”
- Investigate areas where terrain is difficult for land vehicles to traverse

According to Graham Warwick, while missions are still highly restricted, sUAS operators are finding an increasing number of civil applications (Warwick, 2013, p. 60):

Rescuing Hikers

The UK’s University of Central Lancashire (UCLan) has combined [sic] unmanned aircraft and crowdsourcing to help rescue teams find people faster [sic]. Working with the Lake District’s Patterdale Mountain Rescue Team under AeroSee project, a small octocopter was launched on a 20-min. flight over 10 sq. km. (3.8 sq. mi.) of mountains in search of a missing hiker spotted by the research team. Imagery was streamed to the web, and users could “tag” where they thought they saw an injured person. Visual references and GPS locations were relayed back to the team, which could send the unmanned aerial vehicle for a closer look. UCLan says a UAV can cover a large area quicker than a team and – with a community of “virtual search agents” on call to review imagery – could speed rescues and reduce risks to volunteers.

Monitoring Crops

Kansas-based AgEagle has developed a flying-wing UAV designed to collect imagery to enable farmers and agronomists to evaluate crop condition across entire fields. The mechanically launched, battery-powered, laptop-controlled AgEagle can fly for up to 45 min. equipped with a still or video camera, recording color imagery that is enhanced to create Normalized Difference Vegetation Index images that contrast the chlorophyll intensity of healthy and stressed plants. Other uses include determining irrigation flows, surveying storm damaged crops, and looking for lost livestock. AgEagle plans to begin deliveries in the fourth quarter of the year, at a system price of \$10,000.

Managing Wildlife

The U.S. National Oceanic and Atmospheric Administration (NOAA) has tested flying a UAV from a ship in the Olympic Coast National Marine Sanctuary to observe wildlife at relatively close range with minimal disturbance. The tests involved the AeroVironment Puma AE launched

and recovered by the research vessel Tatoosh. The hand-launched, battery-powered UAV has an endurance of about 2 hr. The primary objective is to monitor seabird colonies along the Pacific coastlines, survey other marine wildlife and look for marine debris.

Delivering Medicine

Matternet is a start-up working to establish a network of small autonomous quadcopters that could deliver critical medical supplies in inaccessible regions such as sub-Saharan Africa where most of the roads are unusable in the rainy season. Matternet's system comprises the electric air vehicles, landing stations and routing software that runs the network. The company conducted a field trial in Haiti last year, using a quadcopter with a 10-km (6.2 mi.) range to deliver a 2-kg. (1.5 lb.) payload of medication to a camp set up after the 2010 earthquake. Matternet is trying to raise funding to set up a trial UAV network in Lesotho delivering HIV lab tests to hospitals.

Exploring for Oil

Researchers at the University of Bergen in Norway are using a small UAV to collect data with which to create three-dimensional digital maps of potential oil fields. Developed by the Virtual Outcrop Geology group at the Center for Integrated Petroleum Research (CIPR), the hexacopter carries a lidar [sic] laser scanner, infrared sensor and digital camera to higher elevations more cost-effectively than the leased helicopter that would otherwise perform the task. The data is used to create a digital landscape that geologists can then explore virtually to make estimates of where to find oil and how oil flows, and for research into where to store CO₂, says CIPR.

Recovering Power

Small unmanned aircraft could provide faster, safer and more accurate information on power grid damage after a storm or natural disaster, according to proof-of-concept flights conducted by New Mexico State University (NMSU) for the Electric Power Research Institute. Concluded in early February, the flights involved Aeryon Scout and Adaptive Flight Hornet Maxi unmanned rotorcraft providing real-time imagery of high-power lines from a safe distance, at a fraction of the cost of manned aircraft or manual inspections. NMSU plans to evaluate other small UAVs and sensors for inclusion in a database that will allow the Federal Emergency Management Agency and power companies to select the appropriate system for their requirements.

Defending Wildlife

In 2011, marine wildlife defense organization Sea Shepherd was given permission by the Australian government to fly unmanned aircraft over Antarctic waters. In December of that year, the organization tracked and photographed the Japanese whaling fleet using a UAV hand-launched from its vessel, the Steve Irwin. Since then, Sea Shepherd has used a small land-launched UAV to capture video of seal culling at Cape Cross in Namibia. In South Africa, meanwhile, Falcon UAV has completed field tests involving night flights over game reserves to demonstrate the use of small UAVs for anti-poaching, wildlife conservation and research.

2.6.4 *Mission Scenarios for First Responders Using Multiple sUAS in Controlled Airspace, BVR Operations*

Another sUAS application described by Olaeris, Domesticated UAS Technology is the Aerial Electric Visual Assistant (AEVA) (Dallas Press, 2012). This concept uses several air vehicles installed in locations distributed across a region and remotely piloted from one central location. One pilot can operate multiple vehicles at the same time. The technology includes:

- Gimbaled Day/Night/IR Vision
- Autonomous Operation
- 1 hour endurance fully loaded
- 90 second event response
- Arrival before field personnel

When a 9-1-1 call is made, AEVA can be deployed within ten seconds. AEVA can be sent to the location to provide greater situation awareness of the area of concern before responding personnel arrive. AEVA operates autonomously with robotic intelligence and built-in sense and avoid capability (other aircraft and obstacles), and one-hour endurance fully loaded with camera and sensors. It is weather sealed and provides television-quality, stabilized, unrestricted, full-motion video images of the scene in real-time. This capability lowers response time, magnifies manpower and reduces operating budget for commercial and public safety agencies.

2.6.5 Mission Scenarios Related to Agriculture in Controlled and Uncontrolled Airspace, BVR Operations

Drones that are equipped with the appropriate sensors and automated point-to-point programmable flight capability can be an inexpensive tool to aid in several agricultural tasks (Jennings, 2013):

- Monitoring crops to detect insect or herbivore damage, diseases, drought or mineral deficiencies
- Locate microbes in the atmosphere that could lead to plant diseases
- Inspect fencing around crops for damage

2.7 Scope of Standards Organizations

The following standards committees have been designated by the FAA as industry groups which should develop recommended guidelines and standards for UAS.

2.7.1 RTCA

The RTCA Special Committee (SC-203 UAS) is the standards organization that the FAA designated as the industry group to develop the recommended standards concerning Unmanned Aircraft Systems that weigh 55 lbs. or more. This committee began work in 2005 and concluded its work in May, 2013 under a revised schedule. A new RCTA SC-228 committee began work shortly after that date under new Terms of Reference that are being suggested by the FAA. The scope of the RTCA SC-203 approach was the development of two documents.

The Operational Service Environment Description (OSED) would encompass:

- All current and planned UAS operations that may occur prior to 2025, except those intended to operate strictly within visual line of sight
- All UAS types that are in use or in the final stages of development
- All airspace and operating environments in the current NAS (as described in the FAA NAS Enterprise Architecture, September 2007) including airport surface and off-airport operations
- The operational performance and characteristics of UAS based on known values of existing systems.

The OSED “provides a baseline description of UAS operational functions and performance

characteristics, ATC services, NAS environment and procedures. This information is used to support safety, interoperability, and performance assessments” (RTCA, 2010).

The UAS Minimum Aviation Systems Performance Standards (MASPS) would examine:

- The requirements necessary to bring an unmanned aircraft system into conformance with current standards of performance and behavior of manned aircraft,
- Those aspects that differentiate UAS from manned aircraft, and
- The effects that UAS have on the NAS.

It does not address aspects of UAS that are considered to be no different from those of manned aircraft. This document “provides quantitative performance standards for overall UAS system (and Allocates [sic] functions to subsystems” (RTCA, 2010).

The UAS MASPS was divided into two parts. The objectives of Part 1 and Part 2 are outlined in the revised Terms of Reference in an Appendix titled “Operational Requirements, Functional Requirements, and Safety Objectives of all Airspace and Surfaces.” This Appendix provided the basis for the document that replaced the MASPS Part 1 and 2 documents when the RTCA Special Committee (SC)-203 concluded their work early to allow the formation of the SC-228 (RTCA, 2013).

The SC-203 has now changed direction based upon new terms of reference suggested by the FAA. It has been decided that the SC-203 will be replaced by a new SC-228 committee. Because the SC-203 UAS committee has come to a close, the two MASPS documents have been replaced by one document titled “Operational Functional Requirements and Safety Objectives” (RTCA, 2013). The new RTCA SC-228 UAS committee will now be responsible for completing the development of the UAS MASPS. The focus of the group will be to address DSA and Communications requirements.

2.7.2 ASTM

In 2009, the FAA designated the ASTM Committee F-38 as the organization responsible for developing the industry standards related to small UAS. According to the ASTM Membership Secretary, James Jewell, the FAA ordered two committees to develop standards for small UAS. The first would be the ARC (Jewell, 2010):

The FAA issued order 1110.150 on 4/10/2008 to create an Aviation Rulemaking Committee to make recommendations to the FAA as it prepares to write a Special Federal Aviation Regulation (SFAR) that will provide a path for Small Unmanned Aircraft Systems (sUAS) to access limited parts of the NAS on a regular basis. The Order listed the following issues for Study:

1. Hazard and safety risk analysis
2. Registration process
3. Pilot Training requirements
4. Crew medical requirements
5. Requirements for system certification and continuing airworthiness
6. Economic impact
7. International harmonization
8. Communication latency and vulnerability.

The ASTM Committee F38 would continue the standards development for sUAS (Jewell, 2010):

The following matrix is a summary of the standards that the FAA has asked Committee F38 to develop as priority one and two standards:

Prior.	Sub	Document
1	F38.01	Specification for the Command and Control of sUAS
1	F38.03	Specification for Pilot's Operating Handbook (POC) for sUAS
2	F38.03	Practice/Guide for Training and Certification of sUAS Pilots, Instructors, and School Houses
2	F38.02	Guide for Conducting sUAS Flight Operations in Civil Airspace
	F38.03	Position and Altitude Reporting for sUAS

In October of 2013, the FAA selected Kansas State University as the site for testing the standards that the F38 committee developed for sUAS (Blanks, 2013).

3 UAS Current Research Activity

3.1 NASA UAS Integration in the NAS Project

NASA is currently conducting UAS integration research within the UAS Integration in the NAS Project as part of its Integrated Systems Research Program. This 5-year project began in 2011 and is expected to be completed in 2016.

From the NASA Technology Development Project Plan (NASA, n.d.):

The project will accomplish its goals through the development of system-level integration of key concepts, technologies and/or procedures, and demonstrations of integrated capabilities in an operationally relevant environment with an emphasis towards civil access.

Objectives

- Develop a body of evidence (including validated data, algorithms, analysis, and recommendations) to support key decision makers in establishing policy, procedures, standards and regulations, enabling routine UAS access in the NAS.
- Provide methodologies for development of airworthiness requirements and data to support development of certification standards and regulatory guidance.
- Support development of a national roadmap.
- Establish the infrastructure for the integrated test and evaluation (IT&E) environment for UAS Integration in the NAS simulations and flight demonstrations.

NASA has identified five subprojects to address the technical challenges identified above:

- Separation Assurance/Sense and Avoid Interoperability
- Human Systems Integration

- Communications
- Certification
- Integrated Test and Evaluation

3.2 FAA UAS NAS Integration Simulation Research

Beginning in 2009, the FAA began to use its NAS Integration and Evaluation Capability (NIEC) simulation laboratory at the William J. Hughes Technical Center located in Atlantic City, NJ, to conduct UAS NAS integration research. The goal of this research is to work closely with stakeholders in the UAS community to define operational and certification requirements. The initial NAS integration simulations were conducted to identify the impact of UAS integration on NAS operations. Some of the simulations conducted to date include (Buondonno, Lee, & Baker, 2010-2011):

- UAS Operational Assessment – Marine Corps Air Station Cherry Point, N.C. Simulation Exercise
- RQ-7B Shadow coupled with a Flight Management System (FMS)
- Initial NAS Integration (INI) Simulations
- UAS NAS Integration: RQ-7B Shadow with FMS Simulation
- Multi-UAS Operational Assessment: Victorville ATCT.

The FAA is also conducting research with sUAS under a Cooperative Research and Development Agreement (CRDA) with Insitu Inc. using their ScanEagle.

4 Discussion

Considering the FAA’s plan for sUAS to become integrated into NAS operations by mid-2014, the necessary areas of research supporting this task should be quickly identified and conducted, in order to provide the basis for the regulations and procedures that will allow integration to be accomplished in a safe, effective and efficient manner. Currently, in the United States, commercial sUAS operations are not authorized, primarily because there are no regulations and procedures to support them, whereas, in some other countries (as described in this paper), this is not the case.

The FAA has commissioned an Aviation Rule-making Committee to address sUAS VLOS operations, but this committee has not yet produced usable regulations or procedures that would allow the integration of these operations for commercial purposes. They have, however, announced that modelers will not have to abide by sUAS regulations, as long as their vehicles are used for recreational purposes.

The FAA has also published a UAS CONOPS document titled “Integration of Unmanned Aircraft Systems into the National Airspace System, Concept of Operations, v2.0.” (U.S. Department of Transportation, 2012). This document addresses requirements for UAS operations and equipment, but does not address any special procedures for UAS. Special procedures will need to be developed for UAS because of their peculiar attributes. For instance, UAS will require longer periods of time on the runway for takeoff and landing, while using an onboard camera and a ground crew to get into position or exit the runway. Greater spacing in trail with manned aircraft will also be required because of these delays. sUAS will require special airspace procedures because of their small size and slow speed. All UAS and sUAS BVR operations will have to abide by the requirements of the CONOPS document, but VLOS operations are specifically not addressed here. This means that sUAS VLOS operations still have no specific equipment or procedural requirements, other than those addressed by Advisory Circular, AC 91-57 (Federal Aviation Administration, 1981) covering modelers. It also means that there are no specific procedural requirements for integrating sUAS BVR or VLOS operations into controlled airspace.

In addition to the envisioned sUAS missions that will soon be occurring in Class E and G airspace, there are many public and commercial missions that are also being planned, which will take place in and around large cities. This means that sUAS will be operating within Class B, C and D airspace. These sUAS missions will be both VLOS- and BVR-type operations, depending on the mission objectives. First responders will use both types of operations, whereas much of the photographic and other commercial missions would only be VLOS. Police could use VLOS operations for crowd monitoring or for inspecting a dangerous area before entering. They will also want to be able to operate BVR to chase a suspect, or to send a quick response to an accident or disaster area to see what is happening in real time, before first responders arrive. Coast Guard and Marine Police vessels could launch low-flying sUAS over the waters near large cities (also Class B, C or D airspace) to aid in VLOS or BVR search and rescue efforts. All of these missions will be far less expensive and much more efficient when using sUAS, rather than manned aircraft.

As pointed out in this paper, some sUAS have capabilities which exceed the limits imposed upon their operations by current FAA regulations. For example, manufactures have developed safe technologies that allow fully-automated flight capability for sUAS drones along programmed mission routes. Pilots are always capable of intervention to take manual control of the vehicle. This is similar to a pilot of a manned aircraft using an autopilot. sUAS can also use automation to allow the vehicle to return to the launch point whenever a lost-link occurs or a battery charge warning is activated. These capabilities are safety-enhancing technologies and should be evaluated to determine how they can best be implemented.

Another capability that could be very beneficial to safety can be seen in the technologies employed by AEVA. This type of system uses robotic intelligence to self-separate safely over populated areas at low altitude. It also employs the capability of using one pilot to safely manage several vehicles at the same time. The benefits that this type of capability might provide to first responders should out-weigh the costs incurred to evaluate its possible integration in controlled airspace. Most cities where this type of system would be employed could operate safely away from airport traffic routes, if proper procedures for its use were developed through research. Other sUAS technologies that need to be evaluated through research include those which provide the capability of passing vehicle control from one GCS to another, GCS functionality incorporated into common handheld devices such as iPhones, text-to-speech and speech recognition, and modular architectures to flexibly configure the GCS for multiple tasks.

The required precursor to achieving the integration of sUAS into controlled airspace is the collection of data from research showing how it can be accomplished safely and effectively. It is clear that the FAA needs data that demonstrate how sUAS operations can be conducted under the right conditions with the correct information displays/interfaces, so that the pilot maintains situation awareness with the least amount of workload. As cited in this paper, there are advanced technologies currently available for use in portable ground control stations and hand-control devices that can make this possible today, and new technologies will continue to be developed.

The FAA also needs data indicating what Air Traffic Control and Air Traffic Management procedures, concerning sUAS, will safely allow both VLOS and BVR operations within controlled airspace. Because most sUAS missions in and around large cities will be at very low altitudes, the primary enabler allowing integration will be procedural separation. Human System Integration (HSI) simulations will be able to demonstrate situations where controllers can keep other aircraft separated from sUAS that will be using ADS-B and altitude-reporting transponders, while operating at low altitudes. Most aircraft would be separated from these sUAS vertically at higher altitudes. Other low-flying aircraft (e.g. news or hospital helicopters) would be separated from the sUAS areas of operation horizontally. sUAS mission areas would be separated from airport arrival and departure routes procedurally through pre-flight planning,

using pre-established avoidance zones to determine where not to fly. These research simulations will help to identify the appropriate communications interfaces with Mission Control and ATC, as well as the type of coordination that is necessary. HSI research will also demonstrate the appropriate information displays and interfaces for the pilot to be able to operate according to these procedures without undue workload, while maintaining situation awareness of the mission, as well as other aircraft in the area. Without this supporting research data, these operations will not likely happen on the timetable outlined by Congress and the President.

5 Conclusions

In order to support the development of FAA standards, regulations, and ATC procedures that ensure the safe integration of sUAS into the NAS, data is needed in the following areas:

VLOS

1. Pre-flight planning guidelines, which will enable sUAS VLOS operations that would avoid obstacles and airport departure/arrival routes within controlled and uncontrolled airspace;
2. Manual flight and autopilot-aided pilot information requirements, equipment requirements and crew requirements that would enable safe, efficient and effective sUAS VLOS mission operations within controlled airspace;
3. sUAS pilot training/medical requirements appropriate to VLOS mission operations in both controlled and uncontrolled airspace;
4. Air traffic control/management procedural requirements that would enable safe sUAS VLOS operations within Class B, C, D and E airspace;
5. Safe implementation of advanced technologies such as automated flight, multi-vehicle/single-pilot operations, vehicle handoff from one GCS to another, iPhone GCS and Modular Electronics Compartment for flexible GCS configuration for multiple tasks.

BVR

1. Pre-flight planning guidelines, which will enable sUAS BVR operations that would avoid obstacles and airport departure/arrival routes within controlled and uncontrolled airspace;
2. Air traffic control/management procedural requirements that would enable safe sUAS BVR operations in each of the various classes of airspace;
3. Safe implementation of advanced technologies such as automated flight, multi-vehicle/single-pilot operations, vehicle handoff from one GCS to another, iPhone GCS and Modular Electronics Compartment for flexible GCS configuration for multiple tasks.

6 Recommendations

The following research is recommended to obtain the necessary data identified in the conclusions of this paper:

1. Preliminary sUAS VLOS and BVR HSI and NAS integration simulation studies should be conducted to identify the basic HSI and NAS integration issues associated with the introduction of sUAS mission scenarios within the NAS environment. This type of research was begun with a sUAS VLOS simulation study at NASA Langley Research Center by the sUAS HSI research team of NASA's UAS in the NAS Project.

2. sUAS VLOS and BVR research objectives should be incorporated as additional research variables within simulation studies that are being conducted with larger UAS. Because sUAS mission scenarios typically take place at low altitudes in controlled airspace, they should have little impact on the other research objectives associated with these studies. These studies will help to identify any airspace separation or HSI issues associated with the introduction of sUAS into the NAS. In addition, these studies could provide valuable input concerning the NAS response to the introduction of sUAS missions, as well as any possible integration issues (especially ATC or ATM) that may be associated with them.

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1. REPORT DATE (DD-MM-YYYY) 01-04-2014			2. REPORT TYPE Technical Memorandum		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE Making the Case for New Research to Support the Integration of Small Unmanned Aircraft Systems into the National Airspace System					5a. CONTRACT NUMBER	
					5b. GRANT NUMBER	
					5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) McAdaragh, Raymon; Comstock, James R., Jr.; Ghatas, Rania W.; Burdette, Daniel W.; Trujillo, Anna C.					5d. PROJECT NUMBER	
					5e. TASK NUMBER	
					5f. WORK UNIT NUMBER 425425.04.02.07.02	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) NASA Langley Research Center Hampton, VA 23681-2199					8. PERFORMING ORGANIZATION REPORT NUMBER L-20338	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, DC 20546-0001					10. SPONSOR/MONITOR'S ACRONYM(S) NASA	
					11. SPONSOR/MONITOR'S REPORT NUMBER(S) NASA/TM-2014-218253	
12. DISTRIBUTION/AVAILABILITY STATEMENT Unclassified - Unlimited Subject Category 01 Availability: NASA CASI (443) 757-5802						
13. SUPPLEMENTARY NOTES						
14. ABSTRACT This paper describes the current state of sUAS regulation, their technical capabilities and the latest technologies that will allow for sUAS NAS integration. The research that is needed to demonstrate sUAS NAS integration capability is identified, and recommendations for conducting this necessary research are suggested.						
15. SUBJECT TERMS National Airspace Systems; airspace; unmanned aircraft systems						
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON	
a. REPORT	b. ABSTRACT	c. THIS PAGE			STI Help Desk (email: help@sti.nasa.gov)	
U	U	U	UU	38	19b. TELEPHONE NUMBER (Include area code) (443) 757-5802	