ACRP

REPORT 144

AIRPORT
COOPERATIVE
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Unmanned Aircraft Systems (UAS) at Airports: A Primer

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AIRPORT COOPERATIVE RESEARCH PROGRAM

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Unmanned Aircraft Systems (UAS) at Airports: A Primer

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AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). ACRP carries out applied research on problems that are shared by airport operating agencies and not being adequately addressed by existing federal research programs. ACRP is modeled after the successful National Cooperative Highway Research Program (NCHRP) and Transit Cooperative Research Program (TCRP). ACRP undertakes research and other technical activities in various airport subject areas, including design, construction, legal, maintenance, operations, safety, policy, planning, human resources, and administration. ACRP provides a forum where airport operators can cooperatively address common operational problems.

ACRP was authorized in December 2003 as part of the Vision 100—Century of Aviation Reauthorization Act. The primary participants in the ACRP are (1) an independent governing board, the ACRP Oversight Committee (AOC), appointed by the Secretary of the U.S. Department of Transportation with representation from airport operating agencies, other stakeholders, and relevant industry organizations such as the Airports Council International-North America (ACI-NA), the American Association of Airport Executives (AAAE), the National Association of State Aviation Officials (NASAO), Airlines for America (A4A), and the Airport Consultants Council (ACC) as vital links to the airport community; (2) TRB as program manager and secretariat for the governing board; and (3) the FAA as program sponsor. In October 2005, the FAA executed a contract with the National Academy of Sciences formally initiating the program.

ACRP benefits from the cooperation and participation of airport professionals, air carriers, shippers, state and local government officials, equipment and service suppliers, other airport users, and research organizations. Each of these participants has different interests and responsibilities, and each is an integral part of this cooperative research effort.

Research problem statements for ACRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the AOC to formulate the research program by identifying the highest priority projects and defining funding levels and expected products.

Once selected, each ACRP project is assigned to an expert panel appointed by TRB. Panels include experienced practitioners and research specialists; heavy emphasis is placed on including airport professionals, the intended users of the research products. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, ACRP project panels serve voluntarily without compensation.

Primary emphasis is placed on disseminating ACRP results to the intended users of the research: airport operating agencies, service providers, and academic institutions. ACRP produces a series of research reports for use by airport operators, local agencies, the FAA, and other interested parties; industry associations may arrange for workshops, training aids, field visits, webinars, and other activities to ensure that results are implemented by airport industry practitioners.

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Cover photo: An MQ-1 Predator unmanned aerial vehicle takes off from Creech Air Force Base, Nev., May 11, for a training sortie over the Nevada desert. (U.S. Air Force photo/Staff Sgt. Brian Ferguson)

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FOREWORD

By Theresia H. Schatz
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ACRP Report 144: Unmanned Aircraft Systems (UAS) at Airports: A Primer was developed to assist airports of all types and sizes and their stakeholders in gaining an understanding of UAS and their potential use and impact on airports. Information in the primer includes a glossary of key terms and a background on the current state of UAS operations. The primer addresses costs and benefits to airports, regulatory and community considerations, UAS infrastructure and operational considerations, and UAS safety and security among other issues.

The FAA and other stakeholder agencies are working to safely integrate UAS into the National Airspace System (NAS). Currently the FAA prohibits commercial use; however, public entities are allowed to operate under a Certificate of Waiver or Authorization (COA) and civil entities under special airworthiness certificates. As UAS operations become more common, public airports will begin to receive increased requests to utilize their facilities. There are many factors that will influence airport operations. Therefore, this initial review and analysis of current UAS operations may be helpful to airports and other stakeholders.

Under ACRP Project 03-30, research was conducted by Futron Aviation Corporation in association with Merlin Global Services, LLC, and Whirlwind Engineering, LLC. Surveys were conducted targeting UAS operators, airport operators, and experts in the UAS industry to gather information specifically about UAS operations on and around civilian airports. The surveys served as guides for conversations and interviews with the Department of Defense, civilian airport operators, universities, and FAA UAS test site representatives.

CONTENTS

CHAPTER 1

Unmanned Aircraft Systems at Airports

The civil unmanned aircraft systems (UAS) industry in the United States is experiencing rapid growth. The era of unmanned aircraft sharing the skies with pilots of all types and levels of experience is here. The FAA has permitted UAS to fly in the national airspace system (NAS) since the early 1990s. Today, more and more entrepreneurs are finding new and ingenious uses for advancing unmanned flight technologies. Most of this early growth is in the small UAS segment, but it is only a matter of time before industry leaders will push toward larger aircraft that will require the facilities our nation's airports have to offer.

UAS are no longer new and unknown to the public. The United States military has relied upon UAS or remotely piloted aircraft (RPA) as they are also called, for an ever growing array of missions, many of which are highlighted in the news and well known to the public. Today the news is filled with stories like the efforts of Amazon to begin deliveries of packages to customers using UAS, motion picture companies receiving permission to use unmanned systems in the production of feature films, and agriculture companies working to integrate UAS into the business of growing the nation's food. The possibilities for UAS use are only limited by the imagination of the developers and users, and the continuation of the efforts to safely integrate the systems into the NAS.

The Goal of the Primer

The goal of this publication is to assist airports of all types and sizes, as well as airport stakeholders, in gaining an early understanding of UAS and their potential uses and provide information that will aid in the efficient integration of UAS into the airport environment. The UAS industry is in the very early stages of NAS integration and widespread commercial operations from airports are still believed to be years away. Some airports are actively pursuing UAS business, and others are energetically engaged in research efforts with universities and the newly established FAA UAS test sites. A smaller number of airports that share runways with military airfields are actually supporting UAS operations while commercial air carriers transport passengers to and from their civil terminals. This primer aims to share recent lessons learned by airport operators and owners alike to better prepare the airport industry to take advantage of UAS to the fullest extent possible.

The speed of advancement in the UAS community is not slowing. The airport industry is looking into the future and has a view of what is ahead. Through education and research, the airport industry will be ready to attract UAS business to their facilities and be prepared when the opportunity to support UAS companies arises.

1.1 Elements of the Primer

The primer is organized to inform the airport operator on some of the basics of the UAS industry, the differences and similarities with manned aircraft operations, and some of the lessons learned by airports with early UAS experience. The primer is written at a high level but provides direction toward available resources to which the reader may turn to gain additional detailed knowledge. The primer does not attempt to make the reader an expert in unmanned aircraft operations, but rather touch on key areas to raise awareness and generate thinking on issues airports will tackle. After reading the primer, the airport operator will be ready to dig deeper into the subject, come up with solutions for the current challenges, and generate additional questions that follow-on research might answer to make UAS/airport integration successful and safe.

Areas of Focus In the primer, the user will gain an understanding of:

- Lessons learned from civil and military airfields
- Costs and benefits of UAS at an airport
- Local community considerations for UAS introduction
- UAS regulatory status and issues
- UAS facility requirements
- Airport operational considerations for UAS
- UAS safety and security considerations
- UAS modes of operation and terminology
- Resources for UAS information

The primer can be looked at and used in sections. If an airport operator or UAS operator has specific questions, individual sections can be used autonomously. While some of the information provided flows from section to section, each section of the primer is intended to stand alone and be used as reference material. In some cases, information is repeated in multiple sections to support the standalone feature.

Viewing UAS from the Airport Perspective The primer focuses on the UAS industry from the viewpoint of the airport operator. At present, airport integration is not the focus of the UAS industry. Much of the current research and the initial regulatory efforts are focused on integrating small UAS into the current airspace structure safely. Small UAS, defined as those aircraft weighing under 55 pounds, typically operate independently from airports. Much of what is learned from the integration of these aircraft will likely pave the way for larger commercial UAS that will need airport facilities to operate.

Airspace use and air traffic control issues are not a key area of focus in the primer. The continuous advances in the UAS industry make air traffic deconfliction a key challenge. However, airports do not exist in a vacuum; what happens in the skies directly above impacts facilities and runways on the ground. The primer touches on the aspects of airspace and air traffic that directly impact UAS airport operations as experienced by the early users, such as the role of the airport in the development of a Certificate of Waiver or Authorization (COA), however these two key areas of integration are left for future research efforts to address in full.

A Moment in Time The primer is published at a moment in time. It is anticipated that shortly after its circulation the information will begin to become dated and may not represent the current state of the UAS industry and, even more importantly, the current state of regulation. Airport operators are encouraged to continue to pursue new information and stay in-tune with changes to the industry.

1.2 Sources of Information

Interviews with those most familiar with UAS operations, research, and regulatory efforts were a key source of information for the primer. Interviews were conducted with UAS operators; FAA officials; airport managers and air traffic controllers with experience in UAS operations at civil and military airports; and leaders with the national UAS test sites. Each interview led to additional resources and generated new questions. This is the nature of the industry at present: new information is becoming available seemingly each and every day.

Additionally, members of the research team had experience operating various UAS for the Department of Defense, both for training purposes in the United States and in military operations abroad. The primer incorporates their knowledge and experience as well.

At the time of primer publication, the research team was still uncovering new sources of information. The activities at the selected FAA UAS test sites are in the early stages of operations and new technologies are continuously being introduced. The primer is a starting point for the airport community. The knowledge bank for UAS grows by the day and the primer begins a knowledge exchange process that will enable airport managers to actively serve as members of UAS development and integration teams.

The rapid innovation and rate of growth in the commercial UAS industry is running ahead of regulatory efforts. The FAA is working with the UAS industry to develop rules and regulations to ensure safe integration into the NAS. Commercial companies would like regulators to accelerate their efforts as more and more ways to use UAS technologies developed. The FAA's UAS webpages (https://www.faa.gov/uas/) provide information on where regulatory efforts stand.

Another source for the latest news and information is the Association of Unmanned Vehicle Systems International (AUVSI). The AUVSI is a nonprofit organization working to advance unmanned systems, not only aircraft systems but many different robotic systems. While membership in the association is required to access all resources, the latest news from the UAS world is available using the AUVSI website (http://www.auvsi.org). Additional resources available and used during the development of the primer can be found in Appendix A.

Unless otherwise noted in the text, the information presented in the primer was obtained using the resources listed above.

The primer scratches the surface of the rapidly growing UAS industry and how it will integrate with airports. As UAS operations become more common and the challenges of UAS integration into the airspace are solved, airports will begin to receive increased requests to utilize their facilities. There are airports that are currently working to establish an environment that will attract UAS manufacturers, suppliers, and operators. Airport operators are encouraged to follow UAS experiments, testing, and research closely. The UAS industry is eager to gain access to the NAS for commercial purposes. The resources highlighted in the primer can help airports stay informed and be better prepared when the industry expands to runways across the country.

1.3 Primer Roadmap

In order to get the greatest benefit, it is suggested that the reader use the following roadmap for navigating the primer:

- *Chapters 1 and 2 First* Chapters 1 and 2 provide an introduction to the primer and to the UAS arena. These sections should be read first.
- *Chapter 3 Next* Chapter 3 provides lessons learned from a number of UAS experienced airports, both civil and military. Chapter 3 should be read second with the lessons sparking interest in certain topics that are covered in greater detail in the succeeding chapters.

- *Chapters 4 through 9* The remainder of the chapters can be read at the discretion of the user and dependent upon the topic of interest at the time.
- *Appendices* Appendices A through E add details on topics addressed in the body of the primer and can be used as a standalone reference. In particular, Appendix A and Appendix B may be valuable to the reader. Appendix A—UAS References for Airports—provides the user with valuable resources that can expand the UAS knowledge base of airport operators; Appendix B—Modes of UAS Operations—gives detailed information and examples of how UAS are setup and operated on an airport.

Navigating the primer is illustrated in Figure 1.1.

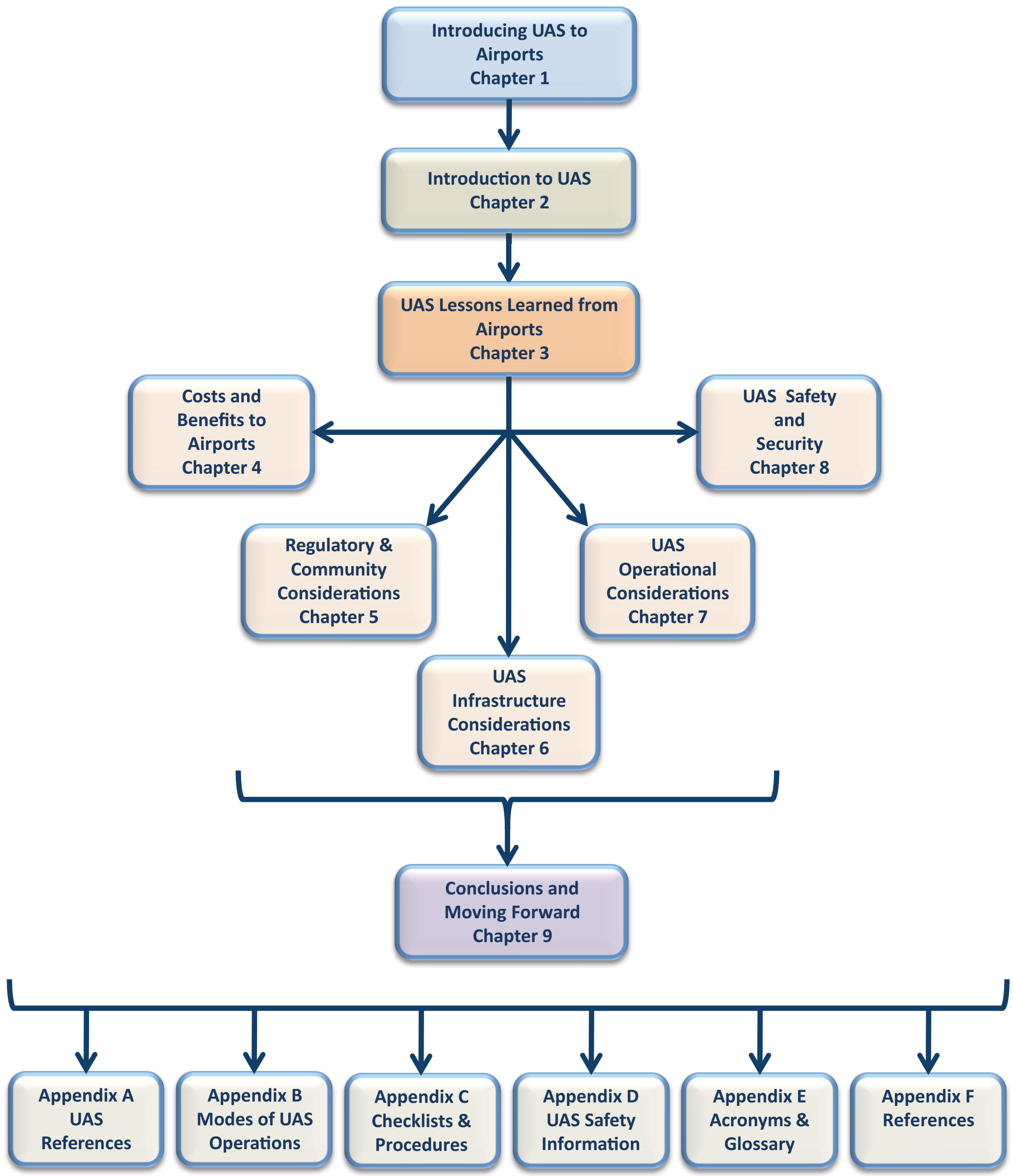

Figure 1.1. Primer roadmap.

Table 1.1. Airport UAS preparation checklist.

Airport Action	Benefits to the Airport
Engage with a UAS National Test Site	Test sites have available segregated airspace; COAs in place; potential research requirements for airports.
Engage with Area Universities	Multiple universities offer UAS related courses; multiple universities conduct UAS research; universities are partnered with national UAS test sites and Center of Excellence proposal teams.
Contact State Government	Departments of Aviation; Commerce, Agriculture and Forestry; Mines, Minerals, and Energy; state police may be potential advocates for UAS business at airports.
Attend UAS Conferences and Seminars	Conferences and seminars on aspects of the UAS industry are conducted regularly to network and become informed on upcoming technologies.
Investigate Complementary UAS Businesses	Research UAS businesses that could be supported by the airport or by the local economy.
Determine UAS Facility/Infrastructure Requirements	Inventory airport facilities and infrastructure that could be used by UAS operators for marketing purposes.
Contact the FAA	FAA Office of Airports (ARP) and FAA UAS Integration Office (AFS-80) can inform and offer direction to interested airports.

1.4 Airport Checklist for UAS Preparation

The primer can be used as a guide for the airport looking to bring UAS operations and business to their community. Table 1.1, a checklist for UAS preparation, is derived from the experiences of airports working to attract UAS manufacturers and operators to their facilities. It is presented to give airport managers a starting point for entry into the UAS industry. Additional details on the checklist items are provided in Chapter 9.

Chapter 1
Chapter 2
Chapter 3
Chapter 4
Chapter 5
Chapter 6
Chapter 7
Chapter 8
Chapter 9
Appendices

CHAPTER 2

Introduction to UAS

The UAS industry is still in its early stages in civil aviation but its growth is rapid. With much of the focus concentrated on small UAS, airports may not see the need to become knowledgeable about unmanned systems at this point in time. However, larger systems like the ones used by the Departments of Defense and Homeland Security are flying in the NAS, albeit under strict constraints, and commercial use of similar systems is on the horizon. Also, current regulatory efforts are allowing small UAS more access to airspace across the country and may take place near airports. Airport operators will be well served in learning the ins and outs of UAS, both large and small, so the impact on airport operations is transparent to airport operators and users alike.

This chapter addresses some of the ways UAS are currently used in the United States and how these uses might impact airport operations. As is continually mentioned in the primer, the industry is dynamic and growing rapidly; airport operators looking to be part of the industry should stay abreast of the latest developments.

2.1 The Evolving Spectrum of UAS

The capability to fly unmanned, high performance aircraft from runways has existed for decades. The U.S. military has flown jet aircraft, such as the F-4 Phantom and F-86 Sabre, remotely since the late 1970s. In 1984, NASA and the FAA cooperated in a research project where a Boeing 720 (an aircraft similar to the 707 that was ultimately not produced in great numbers) was flown unmanned, controlled remotely, and deliberately crash landed to test the survivability characteristics of passenger aircraft. Technology to fly large aircraft from remote locations and land those aircraft safely on a runway, and even upon the flight decks of aircraft carriers, is a reality today. Given the rapid advances in unmanned aircraft technologies, regularly scheduled flights of unmanned aircraft may be a reality in the future for airports of all sizes.

UAS come in many shapes and sizes and have a wide variety of performance capabilities. They range from the very small weighing less than 20 pounds (an example being the RQ-11 Raven), to the largest weighing as much as 32,250 pounds at takeoff and capable of traveling around the world while staying aloft for multiple days (RQ-4 Global Hawk). The FAA and other stakeholder agencies are working to safely integrate UAS into the NAS. These efforts are driven partly by the vision of the stakeholders, and partly by the desire of industry to realize the commercial potential of UAS. Currently, outside of approved exceptions, the FAA generally prohibits commercial UAS use; however, more opportunities to fly are opening up.

In order for the FAA to begin the process of understanding how commercial UAS and UAS in general can safely access the NAS, they have accepted applications for and approved operations at six national research and test sites. The sites are tasked with maintaining an environment for safe UAS operations and information gathering and provide feedback to the FAA on a frequent basis. Later in this primer, the six test locations are identified and discussed in greater detail.

Most recently, the FAA has granted regulatory exemptions to numerous companies, chief among them being film and television production companies along with companies collecting aerial data, to fly small UAS to support their business activities. These exemptions are approved in accordance with Section 333 of the FAA Modernization and Reform Act of 2012, which grants the Secretary of Transportation the ability to approve UAS operations in the NAS on a case-by-case basis in lieu of the grant of an airworthiness certificate. As of the end of May 2015, nearly 500 Section 333 exemptions have been approved by the FAA, with over 350 approved between mid-April and late-May 2015 alone. Section 333 exemptions are discussed further in Section 5.1 of the primer.

Beginning Slowly at Airports UAS operations that involve airports will likely remain associated with government organizations in the near term. Interviews with FAA professionals revealed that the current focus of regulatory efforts will be on small UAS. As technical developments are made to address key safety issues (such as airborne detect-and-avoid systems, civil data links, and privacy and security issues), commercial UAS operations using larger UAS may begin to receive approval, and UAS flights in more populated areas and to larger airports where more sophisticated operations occur may begin to expand.

It is likely that early civil and commercial airport operations will require additional observation resources to ensure traffic separation. As will be discussed in later chapters of the primer, UAS operations at airports mirror manned aircraft operations in many ways. Early successful operations at airports and military airfields have occurred at controlled airfields. Having air traffic control facilities help ensure safe and efficient traffic flow through added surveillance and monitoring. Additional "eyes on" at this stage of industry maturity may provide assistance to any operations. Key airport considerations will be mainly focused around providing the unique infrastructure that is needed to enable UAS operations and support, and the safety systems necessary to ensure an acceptable level of safe operations.

Each System Is Unique As each airport is unique, so is each unmanned system. Every UAS has its own capabilities, nuances, and requirements. Each system needs to be analyzed separately, looking at vehicle size, vehicle performance, operator qualifications, operating procedures, and emergency profiles/procedures. Most of these are addressed during UAS certification, and may or may not be of concern to the airport operator. However, it will help the airport operator to understand the capabilities and restrictions of the systems so that challenges can be addressed proactively.

With the proper planning and analysis, UAS have been able to operate at airports that support normal commercial operations. At Killeen/Fort Hood Regional Airport in Texas, the U.S. Army is operating the Grey Eagle UAS (MQ-1C) on a daily basis while a number of commercial air carriers transport passengers to and from the airport. Another airport on the verge of integrated operations is Syracuse Hancock International Airport in New York, which anticipates beginning UAS operations flown by the Air National Guard late in the summer of 2015. More detailed information and lessons learned on these two airports are provided in later primer chapters.

2.2 UAS Research

Research on the uses of UAS and how unmanned aircraft can be safely integrated into the NAS is ongoing across the country. In December 2013, the FAA announced the selection of six UAS test site operators designated to provide locations and airspace where UAS research flights can be safely conducted, and thus provide the FAA with information on operations and safety considerations leading toward the safe integration of unmanned aircraft into the NAS. A number of leading universities are playing key roles in the conduct of research at the sites. Some of the test sites are conducting flights from airports and are gathering lessons that will likely be useful to the airport industry.

National UAS Test Sites Each of the selected UAS test sites proposed areas of research activities in their proposals to the FAA. Some of the research areas are possible solutions to key concerns such as "sense and avoid" as a substitution for the accepted "see and avoid" concept for manned flight for collision avoidance, command and control, ground control station standards and human factors, airworthiness, lost link procedures, and the interface with the air traffic control system. Each operates under the rules and restrictions of an approved COA; a site can make its resources, facilities, and airspace available for research in any aspect of UAS flight. The test sites provide regular updates on activities to the FAA.

The six selected test site operators, along with their initial proposed areas of research, are:

- **University of Alaska:** Development of a set of standards for unmanned aircraft categories, state monitoring and navigation, and safety standards for UAS operations
- **State of Nevada:** Air traffic control procedures required with the introduction of UAS into the civil environment, and how these aircraft will be integrated with NextGen
- **New York's Griffiss International Airport:** Sense and avoid capabilities for UAS, and the complexities of integrating UAS into the congested, northeast airspace
- **North Dakota Department of Commerce:** UAS airworthiness essential data, high reliability link technology validation, and human factors research
- **Texas A&M University—Corpus Christi:** System safety requirements for UAS vehicles and operations with a goal of protocols and procedures for airworthiness testing
- **Virginia Polytechnic Institute and State University (Virginia Tech):** UAS failure mode testing and identification and evaluation of operational and technical risks areas

Each selected test site will develop research plans that will further the advancement of UAS integration into the NAS. While each test site proposed areas of research concentration during the selection process, there are no restrictions on what research can be conducted by an individual site. Airport operators interested in participating in upcoming research projects are encouraged to contact the test site leads. Additional information on the national test sites can be found in Appendix A.

Operational Test Sites On June 9, 2014, the State of Nevada's test site became the third site to become operational. Some of the initial operations from the test site will be conducted from Desert Rock Airport, a private airport in Mercury, NV, owned and operated by the Department of Energy. Some of the initial flight operations will involve the Insitu ScanEagle, a small UAS that does require a runway to support operations. The purpose of the initial research with the ScanEagle will be to verify that UAS can be operated safety from an airport.

On August 7, 2014, the Griffiss International Airport Test Site began approved operations. The first UAS operations in Griffiss Class D airspace were conducted in late October and early November 2014. They involved test and demonstration flights in a segregated small-scale test area under FAA approved COAs. All flight test operations are being conducted in the NAS. The initial UAS flying has involved limited small-scale testing in a segregated area on the airport under a COA. Flight tests were under air traffic control supervision at low altitudes, and involved line-of-sight operation. Additionally, engineering flight testing and demonstration flights have also been carried out using optionally piloted aircraft (OPA) with a safety pilot on board the aircraft.

Lessons learned from some of the tests sites are provided in Chapter 3 of the primer.

UAS Center of Excellence In May 2014, the FAA released a draft solicitation for the organization of a Center of Excellence (COE) for Unmanned Aircraft Systems. The goal is to create a cost sharing relationship between academia, industry, and government that will focus on research areas of primary interest to the FAA and the U.S. UAS community as a whole. The COE will assist in researching all areas of UAS operations and application, to include challenges that airport operators will likely face when integrating UAS.

On May 8, 2015, the FAA announced the selection of a team lead by Mississippi State University as the COE. Alliance for System Safety of UAS through Research Excellence (ASSURE) is the name of the UAS. ASSURE consists of 21 research universities, and nearly 100 industry and government partners representing 15 different countries.

According to the final solicitation for the COE released by the FAA on August 14, 2014, one of the 11 initial areas of research for the COE will be airport ground operations. This research area will explore such issues as the ability for a remotely located pilot to read airport signage, taxi about the movement area using existing taxiways, and follow air traffic control (ATC) instructions that allow for the interaction and avoidance of collisions with manned aircraft. The initial organizational meetings of the ASSURE team members took place in early June 2015. More information on ASSURE can be found at http://www.assureuas.org/.

2.3 UAS Operations from Airports Now and in the Future

Most of the UAS operations requiring runways are currently conducted by the U.S. military and other government agencies. The FAA anticipates that this will be the case for a period of time. Some of these agencies operate from civil airports and some from joint-use airfields flying a variety of missions both training and operational. Two examples of government UAS that operate from airports are discussed briefly here to illustrate how UAS using runways are integrating with manned aircraft.

UAS at VCV The Southern California Logistics Airport (VCV) in Victorville, CA, is the old George Air Force Base. VCV is host to units of the California Air National Guard and UAS have been flown there for years. Operations at VCV include MQ-1 Predator aircraft with the Guard units looking to operate the MQ-9 Reaper in the near future.

A key fact about the UAS operations at VCV is that they are integrated with manned aircraft operations and traffic are controlled by a contract tower. While the airport does not have scheduled commercial air carrier service, the UAS operators and ATC developed techniques and processes to allow for safe manned and unmanned operations. The aircraft fly under the rules and restrictions set in an FAA approved COA established for Air National Guard UAS operations from VCV.

Under the COA rules at VCV, manned aircraft operations and unmanned aircraft operations are segregated. If a UAS is scheduled to fly, the airport issues a Notice to Airmen (NOTAM) and all manned aircraft movements are held until the UAS is airborne and outside of the Class D airspace. If a UAS is airborne, perhaps in the landing pattern conducting training circuits, and a manned aircraft is on arrival to the airport, the UAS is directed to a preplanned holding point where it loiters until the manned aircraft has landed.

For those flying the aircraft, controlling the UAS from the tower, or managing the operations at VCV, dealing with UAS operations at the airport resulted in very little change to the way business is done. Outside the current restrictions that keep the different aircraft types from mixing, the UAS operate like a manned aircraft; they are just smaller and harder to see.

More lessons learned from VCV are provided in Chapter 3 of the primer.

UAS Supporting the Department of the Interior The Department of the Interior (DOI) operates a large fleet of unmanned aircraft. Currently all of their aircraft are runway independent, using launch and recovery systems that can be transported to the remote regions of the country the DOI manages. Most of the missions flown by the DOI UAS are conducted in sparsely populated areas far from an airport that could support the aircraft. The DOI flies unmanned aircraft to perform such missions as wildfire observation, wildlife tracking, and environmental observation. In addition to these internal missions, the DOI has teamed with the California Air National Guard to use UAS to assist in monitoring large wildfires in the western United States. The Director of Aviation for the DOI envisions that unmanned aircraft will play important roles in augmenting airborne wildfire fighting operations in the future.

As an example illustrating this capability, MQ-1 Predator aircraft from the 163rd Reconnaissance Wing of the California Air National Guard flew support missions during the fighting of the large Rim Fire in Yosemite National Park in the summer of 2013. Operating from their home base at the March Air Reserve Base, the UAS were able to fly to the fire sites, operate for approximately 20 hours per day transmitting real-time electro-optic and infrared video, and help California fire incident commanders on the ground make more informed decisions to help save property, infrastructure, and lives.

The DOI envisions that UAS will be used not only to monitor fires but to fight them from the air as well. The size of the aircraft necessary to carry and drop fire retardant or water will require airport facilities for support. An option for this type of mission might be pilot-optional aircraft, such as the Kaman K-Max Unmanned Aerial Truck, or perhaps specially configured helicopters, such as the Little Bird or UH-60 Blackhawk. Having such aircraft available with the option to be flown to and from the airport by a pilot to the area of operations could simplify the challenges facing airports while enhancing mission capabilities for the operators. Such unmanned assets could potentially augment aerial firefighting efforts with a night flying capability currently assessed to be too risky for manned aircraft.

CHAPTER 3

Airport Lessons Learned

When an airport is starting down the path toward bringing UAS business and operations to their facility, the first question management is likely to ask is, "What have airports working with unmanned aircraft learned that can help us succeed?" This chapter of the primer presents lessons from both civilian airports and military airfields, putting key points up front.

Civil airports and military airfields with UAS operating experience have found that in many ways unmanned aircraft can be treated just like manned aircraft. From the facilities to support the aircraft, to the training required for emergency responders, to markings on the taxiways, airports may need only minor modifications to bring UAS into the current environment. There are important differences at present that are manageable and often dependent upon the aircraft type. Airport managers will likely benefit from making themselves knowledgeable on the experiences of other airports and conducting in-depth planning to better ensure successful and safe integration.

3.1 Southern California Logistics Airport (VCV)

One of the early airports to integrate UAS into their operations was the VCV, which began operating UAS in 2006. Many of the UAS lessons learned at VCV are presented in a paper entitled, "Controlling UAS Flight Operations in a Mixed-Mode Environment Today" (Smith and Taylor 2013).

The primary UAS operator at VCV is the California Air National Guard. The Air Guard flies the MQ-1 Predator and will soon begin operations with the MQ-9 Reaper. The MQ-9 is similar in length and weight to a Beechcraft King Air, with a wingspan about 30% greater than the King Air. Boeing Corporation previously operated prototypes from VCV, but has since moved those operations to another site. VCV has COA in place to fly to and from military operating areas and restricted airspace in southern California.

- **Airport facilities:** VCV had facilities in place that could handle the needs of the Air National Guard. When the Air Guard needed different facilities for unique aircraft or mission needs, the Air National Guard would construct the new facilities. The regulations and requirements for building military facilities are very similar to FAA construction requirements.
- **UAS ground operations:** Taxiing of unmanned aircraft at VCV is very similar to other aircraft. The remote pilots talk directly with the tower controllers and are able to follow all instructions. The biggest difference with UAS is the slower speed of taxiing. VCV manages the difference procedurally and with real-time direction to pilots.
- **UAS takeoffs and landings:** The biggest concerns during UAS takeoffs and landings are wake turbulence, winds, and visibility. VCV is home to a large aircraft maintenance facility, thus heavy aircraft fly in and out of the airport. The pilots and controllers are required to be extra vigilant and conservative during UAS takeoffs and landings after heavy aircraft operations given the size, weight, and extended wingspan of the UAS.

The operating environment in the desert of southern California often produces strong winds and significant airport crosswind conditions. The winds can create another common environmental hazard: low visibility due to blowing dust and sand. These conditions can limit UAS operations to certain runways.

VCV is in close proximity to a nontowered general aviation airport and therefore often has additional light aircraft traffic in the area, to include flight students, which can transit through the Class D airspace. Procedures, including COA restrictions, communication practices, and segregation of aircraft, minimize the chances of conflicts.

- **Operating with high performance aircraft:** In the early stages of UAS work at VCV, the unmanned aircraft occupied that same airspace as manned aircraft to include the landing pattern. The mix of aircraft often included FA-18, F-16, F-22, commercial passenger aircraft, and helicopters. This mixing of traffic was managed by the controllers in the tower. Separation between the aircraft and clear, concise communications with the pilots allowed for safe and efficient operations.

  As the UAS operations increased at VCV, the FAA partnered with the Air National Guard and the ATC to establish COAs allowing the larger UAS to transit to nearby military operating areas and for the flying of small, hand-held UAS used in training by National Guard units to operate in simulated urban areas on airport property. The COAs segregated UAS operations from manned aircraft and limited UAS operations to one aircraft at a time.

  When a UAS is in the landing pattern at VCV and a manned aircraft is approaching the airport for landing or an aircraft is taxiing to the runway for takeoff, the UAS is directed to depart the pattern to a preplanned holding point until the manned aircraft is clear of the Class D airspace.
- **Night operations:** VCV does conduct night UAS operations. To ensure safety of flight, the airspace is sanitized through scheduling and ATC so that only the UAS are flying.
- **COA development:** The VCV COAs were developed and submitted by the UAS operators. At VCV, the airport did not play an involved role in the COA drafting and approval process.
- **NOTAMs:** NOTAMs are used at VCV to notify other organizations of upcoming UAS operations. Coordination and NOTAM drafting is handled by the UAS operator at VCV, in this case the Air National Guard.
- **Training of airport personnel:** No additional training for airport personnel was required at VCV. Simple familiarization on the characteristics of the UAS aircraft and the airframe materials was provided to aircraft rescue and firefighting personnel. Outside of this familiarization and on-the-job training and experience, no new training courses were instituted.
- **Lost communications with the UAS:** Since 2006, VCV has experienced only two lost link situations with UAS. In each of these instances, the aircraft proceeded automatically to the preprogrammed holding point and commenced the preprogrammed, automatic recovery procedure at the planned and predicted time. The transponders on the UAS transmitted a lost link code which was seen by tower controllers, thus triggering preplanned procedures for the recovery of the UAS.

3.2 Killeen-Fort Hood Regional Airport (GRK)

Killeen-Fort Hood Regional Airport (GRK) is in Killeen, TX. The U.S. Army has units flying the UAS from the airport. MQ-5B Hunter and the MQ-1C Grey Eagle are the two primary UAS flown at GRK. UAS operations are normally conducted four days a week, with an increased level of operations anticipated in the near future.

Of note, GRK is a military airfield with a civilian passenger terminal as an airfield tenant. GRK is served by three major airlines or their contract regional carriers, and supports 26 scheduled commercial operations each day.

Here are some key lessons learned from GRK:

- **Airline-UAS schedule deconfliction:** GRK UAS units use the NOTAM system to keep other flying organizations, including the airlines, informed of upcoming UAS operations. No special coordination is done between the airlines, the UAS operators, and ATC. The UAS operators are familiar with the schedule of the airlines, they understand the necessity of not delaying airline departures or arrivals, and schedule their operations accordingly. The NOTAMs also inform the general aviation pilots in the area of UAS operations so they are aware and can include UAS considerations into their flight planning.
- **Lost link loiter point planning:** According to personnel at GRK, proper planning of UAS lost link loiter points and emergency holding points involving the airport, the UAS operators, ATC, and the local community is a very important aspect of successful UAS integration. A spot must be selected that is not above a populated area, does not interfere with the airport's traffic patterns, and will not result is land-use issues should an aircraft go down while in holding.
- **Coordination meetings:** GRK hosts regular meetings with all airfield stakeholders to discuss issues relating to UAS operations. Some key issues that have been resolved in these meetings include the solving of terminology differences, the training requirements for new airport and UAS personnel, and the development of new procedures following conflicts created by the UAS operators performing brake checks while in the movement areas.
- **Standard operating procedures and airfield doctrine:** When UAS operations began at GRK, there was little guidance upon which to base the development of airfield procedures. Airfield operations personnel, the UAS operators, and ATC developed local procedures as they gained experience. Airports looking to begin UAS operations will be well served by leading the effort to research and develop standard procedures and airport policy that will likely provide the means for a smooth UAS introduction.
- **Airfield education for UAS maintenance personnel:** Many of the people working on UAS at GRK do not come with aviation backgrounds. Many were not be familiar with airfield procedures and safety practices. This issue resulted in an incident at GRK. Following night maintenance work by Army UAS personnel repairing system equipment close to a runway, the maintenance personnel called the ATC and let them know that they were clear of the runway. In reality, support gear had been left next to the active runway creating an obstruction. As a result of this incident, GRK instituted an indoctrination training program for UAS operators, akin to airfield driving training, to enhance safety on the airfield.

3.3 Golden Triangle Regional Airport (GTR)

The Golden Triangle Regional Airport (GTR) serves the cities of Columbus, Starkville, and West Point, and the counties of Lowndes and Oktibbeha in Mississippi. GTR offers a variety of general aviation services to include flight training and charter service; is adjacent to the Lowndes County Industrial Park and the GTR Global Aerospace Park which is home to several international and domestic industries; and offers daily scheduled air carrier service.

Recently, GTR made preparations to begin UAS operations with the Israeli Aerospace Industries (IAI) Heron aircraft. The Heron was to be flown by airport tenant Stark Aerospace; however, flight operations never took place as a result of company business decisions made by IAI. The lessons learned by GTR during their preparations for flight operations could be of value to other airports looking toward UAS operations with a civilian industry partner.

- **Division of airspace:** GTR worked with Stark Aerospace to develop and receive approval for flying the Heron to and from designated test airspace. The biggest question for all stakeholders was whether or not approval would be granted to fly the aircraft in the Class D airspace. The initial perspective of the FAA was the Class D airspace would need to be cleared completely of other aircraft. GTR, Stark, and the FAA worked on a plan to divide the Class D airspace with the UAS flying only in the western half (GTR has a single north-south runway—18/36). The only time complete segregation of aircraft was required was when the UAS aircraft was on the runway. Otherwise, aircraft could come and go from the airport and separation was to be managed by ATC.

- **Line-of-sight ground communications:** Communications antenna placement on the airport is an important factor in safely taxiing some unmanned systems. During the ground testing of the Heron UAS at GTR, it was discovered that the site chosen for the communications antenna did not allow for a clear line of site to all movement and non-movement areas of the airport where the UAS operated. The solution was to install the antenna on the roof of a hangar, with the ground control station trailer placed beside the same hangar. This configuration change eliminated lost link situations on the ground.
- **Specialized power and ground procedures:** As described in Chapter 2 of the primer, many unmanned systems have unique requirements that may require specialized procedures for the airport. The Heron has an advanced navigation system. It incorporates an emergency landing system that can fly to a laser designated spot. An issue for GTR was devising a way to get the required power source to the runway to make the laser designator operational during emergency landing situations. The solution used at GTR was to have temporary power cables at the ready that could be run out to predetermined laser setup spots on the airfield. Another unique aspect of the Heron for the airport was its size. Like other larger UAS, the Heron has a fuselage similar in size to a light general aviation aircraft, like a Cessna 172, but has a wingspan that is closer to that of some regional jets. To reduce the risk of ground collisions when moving the Heron, GTR instituted a procedure where the aircraft were towed to a spot just short of the movement area, at which time the UAS pilot took over taxiing the aircraft.
- **Active participation in the COA development process:** In contrast to the more hands-off approach taken by the Southern California Logistics Airport, GTR was very involved in the COA process. One of the biggest issues in bringing in UAS activity for the airport was to ensure that other airport operations were not disrupted. As stated earlier, the initial drafts of the COA would have required the airport to essentially shut down all other activity when the UAS were to operate. GTR was engaged and proactive in the process, and the COA and associated airport procedures that were drafted provided a manageable operating solution for the airport.

With two UAS manufacturers located at the airport, the management of the GTR continues to work to attract new UAS business. This is done through attendance at trade shows and airshows, letting businesses know about their facilities, capabilities, and experiences. Having gone through the process of establishing an airport environment for UAS, GTR now has a template for future COAs and understands everything can be done within the rules as long as the airport is involved.

3.4 Syracuse Hancock International Airport (SYR)

Syracuse Hancock International Airport (SYR), located in north-central New York, is a joint-use airport sharing runways with Hancock Air National Guard Base. The airport serves multiple airlines with approximately 20 to 25 departures and arrivals each day. The average number of enplanements per year averages around 1 million passengers. Hancock Air National Guard Base is home to the 174th Attack Wing of the New York Air National Guard, which includes a formal UAS training unit. Units in the Wing fly the MQ-9 Reaper UAS. Military flight operations at SYR have dwindled over the years, with a small number of C-17 flights making up most of the limited activity.

SYR is partnered with the Griffiss International Airport UAS Test Site. SYR is working toward becoming the first civilian airport to operate regular UAS operations. The UAS units at Hancock are working with SYR, the local ATC, and FAA controllers at Boston Center to test procedures and familiarize personnel on the unique aspects of UAS operations. The training areas for the SYR based UAS are near Fort Drum, NY, which is more than 80 miles from Syracuse. At present, the UAS must be transported using trucks to Fort Drum, making the logistics of training very challenging. With the approval of UAS flights from SYR, the cost and time to train the operators will likely be reduced. The first flights from SYR are planned to take place in August 2015. Here are some of the lessons learned as SYR prepares for UAS operations.

- **Using all available resources to ensure traffic separation and safety:** In order to ensure all traffic is able to move about the airport safely and efficiently, the airport and UAS stakeholders are planning to use multiple resources to include the tower controllers, ground based visual observers to track the aircraft on the ground and in the landing pattern, and chase aircraft to follow the UAS to the operating areas. Additionally, the Air National Guard units are planning to bring a 3-D ground based radar to the field, as well as a ground based sense and avoid system to enhance situational awareness. Another factor that adds to the safety margin is the UAS pilots are qualified Air Force pilots with extensive knowledge of flight rules and procedures.
- **Familiarizing ATC:** The airport and the Air National Guard units have worked with controllers to familiarize them with the operations capabilities of the aircraft and the flight procedures. SYR has learned that as people become familiar with the operations, they become more flexible in their approach to expanding the envelope of operations. SYR is implementing a multi-phased approach to beginning UAS flights. The steps include taxi tests to validate the site models for locating communications towers and meetings with Center controllers to iron out airspace and transit route issues. Personnel at SYR have also learned that a system like the MQ-9 can be treated as another aircraft once the stakeholders are familiar with the aircraft and its system requirements.
- **Confidence in lost link procedures and holding locations:** SYR, like Killeen-Fort Hood Regional Airport, has learned that ensuring the lost link procedures, holding points, and emergency flight termination points are thoughtfully planned out. SYR has several local communities very close to the airport. The airport and the UAS operators are looking carefully at flight routes and holding areas to ensure they maintain the confidence of the surrounding communities.

3.5 Additional Lessons Learned from U.S. Military Airfields

The U.S. military has operated UAS, or RPA as the Air Force now refers to their systems, for nearly two decades. Air Force and select Air National Guard units have much experience with aircraft that operate from runways. Their aircraft range from the MQ-1 Predator and the MQ-9 Reaper (similar in length to a Cessna 172 but with a wingspan close to that of a regional jet), to the RQ-4 Global Hawk (a UAS with a wingspan greater than a Boeing 757).

The Army also operates aircraft that utilize runways with varied modes of operation. The Army's MQ-1C Grey Eagle is similar in size to the Predator, burns jet fuel in a diesel engine, and, perhaps most importantly from an airport perspective, it takes off and lands in a fully automatic mode.

The following lessons learned come from various Army airfields flying the Grey Eagle and from Cannon Air Force Base in Clovis, NM, where the Air Force is flying a variety of unmanned aircraft.

- **Takeoff checks on the runway:** As described earlier, all UAS have unique characteristics to include the takeoff and landing modes and procedures. In preparation for its automatic takeoff mode, the Grey Eagle needs to sit on the runway for up to 2 minutes prior to departure as navigation and communications systems are brought online. This preparation requires a significant amount of equipment near the end of the runway. This combination effectively closes the runway to civil use until such time that the equipment can be removed. This aspect of certain UAS will be discussed again in Chapter 4, as well as in Appendix B.

- **Experience of UAS operators and pilots:** Those who fly or operate military UAS come to their jobs with varying degrees of experience and training. The U.S. Army flies a large number of UAS that have automatic takeoff and landing modes whereby the operator takes over after takeoff and directs the UAS via digital commands. Early in the introduction of such systems, the proficient Army operators were often unfamiliar with airport operations, airport facilities, and in some cases were not familiar with airport markings or lighting. The U.S. Army now includes a ground school with all UAS operator training courses to address this issue. Varying degrees of knowledge and experience will likely be an important issue as the UAS industry grows and may impact airport operations on or near the airfield.
- **Tracking UAS:** Tracking the location of UAS in relation to the airfield and to other air traffic is important and can be a challenge. UAS typically fly in good weather using visual flight rules, and around controlled airfields they are normally handled using positive control and under instrument flight rules. At Cannon Air Force Base, the control tower utilizes a Radar Slave that receives signals from the nearest radar antenna. This allows the airfield to maintain situational awareness of UAS positioning given the difficulties facing the UAS operator in providing accurate position reports when outside the radar coverage of the airfield.
- **Understanding UAS operational characteristics:** It is important for airport operations personnel and ATC to familiarize themselves with the individual characteristics of the systems and the ground procedures for the aircraft operating on the airfield. In the early stages of UAS operations at Cannon, the ATC was caught off guard by the UAS pilots being ready to receive their flight clearances as soon as the aircraft started its engines.
- **Frequency of UAS lost link:** The UAS operators at Cannon fly approximately 300 missions annually. During about 10% of the flights, the aircraft loses data-link connection with the pilot. More often than not, communications with the aircraft are regained within a few seconds and the aircraft continues its flight. The frequency of lost link illustrates the importance of lost link loiter point planning.

CHAPTER 4

Costs and Benefits to Airports

Airport operators have a working knowledge of the typical revenue sources that support their facility. With commercial use of UAS on the horizon, airport operators envisioning UAS operations as viable and compatible with their operations may consider several areas when analyzing the potential costs and benefits.

The information in this chapter comes from discussions with airport operators with UAS activities currently on their airport, ATC staff with experience controlling UAS, and universities supporting the six FAA UAS national test sites.

4.1 Vision for UAS Operations

A prerequisite to determining the costs and benefits of UAS integration is to develop a vision of what future airport business and operations will look like with unmanned systems in the mix. Typically, 14 CFR Part 139 certificated airports have and maintain an airport master plan. According to the FAA guidance (Advisory Circular 150/5070-6B), an airport master plan is the airport's blueprint for long-term development with one of the goals being to identify a realistic financial plan to support the development. Airport operators who believe UAS operations are possible at their airport might use the master plan as the vehicle that proposes and guides the realization of the vision. The airport master plan is based upon forecasted aircraft operations and passenger numbers and provides a blueprint for the improvement of airport facilities. A vision for UAS operations could be integrated into the master plan, or an airport strategic plan or financial plan if those are more applicable vehicles, and take into consideration tasks needed for UAS development and provide a roadmap for this change in airport operations.

A publication that may be of benefit to airports considering this change is *ACRP Report 76: Addressing Uncertainty about Future Airport Activity Levels in Airport Decision Making.* The report provides a guidebook on:

> . . . how to develop air traffic forecasts in the face of a broad range of uncertainties. It is targeted at airport operators, planners, designers, and other stakeholders involved in planning, managing and financing of airports, and it provides a systems analysis methodology that augments standard master planning and strategic planning approaches. (Kincaid et al. 2012)

While *ACRP Report 76* was not specifically published to address UAS forecasting, it is a resource for airport operators that want to understand the process of looking ahead. The guidebook can assist airports in planning for UAS integration and expansion. It provides a process for determining what is possible and likely at a particular airport in terms of aircraft operations and activities necessary to support UAS.

Considerations for an Airport UAS Vision

There are two overarching considerations that stakeholders would be well served by addressing when developing the airport UAS vision. First, have the airport consider the types of UAS that can be expected and the number of operations anticipated. Second, have the airport determine the facilities necessary and currently available for UAS activities, including a communications infrastructure. Both of these considerations will likely have major impacts on attracting and maintaining revenue streams from UAS activities.

Types of UAS The type of UAS operating from the airport will likely drive the possible revenue streams. Larger UAS that require runways, ramps, and hangar space are likely to provide more opportunity for revenue to the airport and the surrounding community. The larger UAS will utilize more facilities and require more support than smaller UAS. Many small UAS are hand or truck launched and considered airport independent. While small system operators may desire to use an airport as a base of operations, their independence can limit the potential for increased revenue to the airport and the community.

The operational requirements for runway dependent UAS vary from system to system. Airport planners and operations personnel will need to understand the system requirements prior to commencing the planning for operations.

For many systems, unmanned aircraft can be treated the same as manned aircraft by the airport staff. For example, the MQ-1 Predator taxis to the runway, takes off, and lands as a light general aviation aircraft would as the pilot controls the aircraft and communicates directly with ATC.

Other systems have very different modes of operation that will impact the airport. The MQ-1C Grey Eagle is similar in size and appearance to the Predator but is handled very differently on the runway. The Grey Eagle uses automatic modes for takeoff and landing with the operator taking control once the aircraft has reached a certain position and altitude. The aircraft is towed onto the runway and requires a period of time, perhaps two minutes, to align the systems and conduct pre-takeoff checks. These procedures, along with the equipment that is required on or near the runway, have an impact on airport operations for this system and need to be included in airport planning.

Airport Facilities It is generally true that airports today have either fully utilized facilities or are looking to remove or transform existing, older facilities. New investment is often hard to come by and therefore new facilities that could be available for immediate UAS use are equally hard to come by. The airport operator should understand and plan for what facilities are now available for unmanned systems, or facilities that may be repurposed in their use. Examples might include:

- Vacant hangars (even general aviation T-hangars might serve a UAS purpose)
- Vacant office space
- Industrial park space adjacent or in close proximity to airport property
- Vacant operational space (perhaps an available communications center left by an air cargo operator)
- Ramp space
- Vacant land that is planned for or has airfield access
- Utility capacity (e.g., water, sewer, electrical power, natural gas, and fuel access)

UAS ground control stations may also require on-site storage (hangar capacity). The operators of the larger UAS are often relatively self-sufficient, utilizing vehicles and mobile control stations that can be located within the hangars. There may not be a need to provide a special control room or center for UAS operations in a new facility.

All of these types of facilities or property might have a purpose for UAS operations. With little or no investment, they could provide the airport with an attractive environment for a UAS operator. The airport operator should know what they have and what it might take to put the assets to use for UAS operations.

4.2 Airport Revenue Streams Associated with UAS

Most airports have a structured way in which they obtain necessary revenue to cover operating costs and make capital investments. ACRP has produced, or is in the process of producing, resource materials that may assist an airport operator in understanding and developing revenue streams from UAS operations. While these publications are not UAS specific, they provide information that might be helpful in structuring a cost recovery system (revenue streams). They include but are not limited to:

- *ACRP Report 33: Guidebook for Developing and Managing Airport Contracts*
- *ACRP Report 36: Airport/Airline Agreements—Practices and Characteristics*
- *ACRP LRD 23: A Guide for Compliance with Grant Agreement Obligations to Provide Reasonable Access to an AI–Funded Public Use General Aviation Airport*
- *ACRP Report 106: Being Prepared for IROPS: A Business-Planning and Decision-Making Approach* (UAS operations might initially be considered IROPS)

When planning for UAS related revenue streams, airport operators are well advised to understand how their facilities and airport properties are encumbered or limited in their use because of local tax codes, zoning laws, grant assurances [FAA AIP (Airport Improvement Program)], or other issues that might restrict the airport. An airport operator may find that the UAS operator requires a lease, contract, or use agreement that has substantial financial differences from existing agreements for similar facilities. This may cause issues for the airport operator, and the legal requirements associated with such an agreement should be investigated and fully understood before entering into such a relationship.

Given a full understanding of how a lease, contract, or use agreements for airport facilities might be structured, an airport operator should consider the following opportunities for revenue streams from UAS operations:

- Fuel flowage fees (dependent on fuel type)
- Landing fees (dependent on runway use and or adjacent land use)
- Hangar rent
- Ramp space rent (including tie downs)
- Office space rent
- Operations or communications center rent or use fees
- Industrial park space rent or use fees
- Special emergency equipment and staff standby or response [if UAS operations require aircraft rescue and firefighting (ARFF) or other emergency response equipment to standby for normal operations, then perhaps a premium might be charged for this type of service]

Airports may benefit by making sure the rates for services and facilities paid by UAS operators are comparable to those paid by the manned aircraft community in order to avoid conflicts and ensure operational cooperation.

Revenue from Additional UAS Support It is commonly accepted that UAS operations require more support than manned aircraft from the ground and perhaps in the air because of the necessary communications and control protocols. This additional support manifests itself in more trucks, buildings, communication/operations centers, etc. The additional burden on the airport, its facilities, and resources should be recovered financially. Otherwise the UAS becomes a negative revenue flow to the airport. If the airport receives grant funding, it is important for airport management to have a discussion with their FAA Airport District Office (ADO) prior to executing UAS leases, contracts, or use agreements.

Generally speaking, where larger UAS are operating and have been operating for some time, the communities around those airports have experienced growth in additional services required to support the additional personnel who build, operate, and maintain UAS. At the GTR, UAS manufacturer Stark Aerospace located personnel and business operations at the airport. At SYR, the New York Air National Guard (while not a commercial organization) located UAS operational units at the airport as other Air National Guard flight activity began to subside. This brought Air National Guard personnel and their families to the area thus contributing to the economic growth of the community.

The same can be said for any additional operations at an airport. Once the operation becomes well established and requires more people, equipment, and materials, the local community is usually the benefactor from such economic growth. Establishing a baseline of economic activity at an airport whereby the economic contributions of UAS operations can be measured should be of consideration to airport operators. The ability to demonstrate growth will likely aid in developing future community and political support.

4.3 Infrastructure Considerations and Costs

As discussed previously, airports are well advised to understand what they have available, what is possible with the facilities and airspace, and what may be required in the form of investment in order to make the facilities usable for UAS operations.

Initial Infrastructure Questions The considerations for infrastructure requirements should start with some basic questions from the airport to the UAS operator:

- Does the UAS need a runway for takeoff, landing, or both? If so, what runway length and width is required?
- Can the UAS taxi to/from the runway and follow ATC commands and other voice commands?
- Does the UAS need hangar space when not flying?
- Does the UAS need ramp space prior to or after flight?
- What sort of control station is required (truck, trailer, office space, etc.)?
- Does the UAS need launch and recovery space (in lieu of a runway)? If so, how close to the airport does this space need to be?
- What sort of communications infrastructure is needed? Does the UAS operator need special towers of antennas in order to ensure communications are established and maintained with the UAS?
- Will the communication frequencies needed create conflicts? Will they interfere with existing frequencies used by airport staff, the FAA, tenants, airlines, fixed base operators, or others?
- Will the UAS need special emergency standby equipment? Is it available at the airport or does it need to be brought in from an outside source? As an example, a large general aviation airport might need to bring in a local fire department truck to standby for UAS operations as a matter of protocol.

As mentioned earlier, the airport needs to recover the actual costs for the facilities and services used by the UAS operator. The mechanism for recovering those costs should reflect the ones already in use by those individuals and organizations that use the airport. If new facilities or services are necessary to accommodate a UAS operator, the airport operator and airport owner will need to determine if these are recoverable costs. Will UAS related costs and revenues go toward the long-term development and expansion of the airport? If so, should they be funded by the airport? Or will additional costs be absorbed by outside agencies and investors who have a stake in the airport's success?

Current Facilities Available for UAS As the airport makes preparations for bringing in UAS, taking inventory of available facilities that potentially meet UAS operator needs is an important early step. The goal of the inventory is to help ensure an airport does not turn UAS operations into a negative revenue situation. To the extent possible, UAS operations should be considered by airports with a master plan already established; the UAS component of the operation might be a consideration during the next master plan update.

For those airports without a master plan, perhaps a business plan has already been established and can be updated accordingly. For those smaller airports without a tool for long-term planning, it is recommended that a simple inventory of the facilities be developed. It should consider the following:

- Unleased and unused ramp space
- Unleased and unused hangar space
- Available office space
- Available storage space
- Airspace restrictions
- Communication frequencies actively used by all users of the airport as well as those located nearby (a trucking company with distribution warehouses, as an example)
- Any FAA ATC restrictions (does the tower close for part of the day)
- Emergency response capabilities

After taking an inventory of what is available, the airport operator can then estimate the costs associated with these facilities and services should they be leased or used by a UAS operator. The costs of UAS operations should not become a negative cash flow situation for the airport. This information is necessary for a cost recovery discussion with the UAS operator.

Funding New UAS Facilities If new facilities and services are necessary to accommodate UAS operations, their funding sources for them should be an early topic of discussion with the UAS operator. If the UAS operator is attracted to the airport as a result of favorable airspace, available ramp space, near the testing areas, close proximity to the mission areas, or other factors, the airport may be able to leverage these possible advantages and ensure the UAS operator assists with the cost of its operation and any necessary capital investments.

Regardless of costs and the UAS operator needs, there may be the possibility that the local political environment drives the airport to pursue and retain UAS operations as a means to improve revenue to the airport or to provide revenue and job growth to the local community. Given this possibility, the airport operator is advised to know and understand the desires of the airport owners and their political representatives or elected officials. This is critical if the airport's cost recovery model includes taxes from local government, such as a hotel tax or local property taxes that may go to support the local airport. If this is the case, the elected officials may feel as though they have a substantial stake in how the airport is operated and developed. The airport operator needs to identify these types of issues before a UAS opportunity becomes known. In order to stay ahead of such a possibility, the airport operator needs would be well served by having as much information about UAS as possible and initiate discussions with the appropriate political representatives in order to identify potential issues and how they are to be resolved.

4.4 Engaging the Public and Surrounding Communities

Airports looking to introduce UAS into their operations will be well served by actively reaching out to their local communities. The purpose of the outreach should be to educate the public on the aircraft to be flown, the types of activities the UAS will perform, and the risk mitigations implemented to ensure public safety. UAS are an unknown for most. They are referred to as "drones" in the news media, and drones are the aircraft many people only know as those that collect intelligence and fire weapons for the military.

Understanding local politics and public perceptions will be important for the airport operator prior to pursuing UAS opportunities. Although the awareness of UAS is growing as the industry grows, it is likely that a percentage of the public have particular views on drones that may not be accurate, and could impact the airport's ability to bring UAS business to the community.

Multiple incidents involving UAS have been newsworthy in 2014 and 2015. On January 26, 2015, a small UAS crash landed inside the grounds of the White House in Washington, DC. Two near miss incidents between commercial aircraft and UAS in March of 2014, one near Tallahassee, FL, and one near Perth, Australia, made headlines and brought to light key airspace and safety issues facing the aviation industry.

In another event that will likely have an impact on the use of UAS for commercial purposes, the NTSB in November 2014, while ruling on a decision by the FAA to levy a $10,000 fine on a person for flying a small, remote-controlled UAS to film a promotional video, determined that anything that flies is defined as an aircraft, whether it be a manned aircraft, a classic model aircraft, or a small UAS. The case highlighted the ability, and the need, for the FAA to regulate UAS to ensure the safety of the public.

These are but a few examples of a large number of incidents involving UAS in the last couple of years. These types of incidents work to influence public opinions on UAS, perhaps feeding skepticism and fears over the presence of unmanned aircraft in the community. The airport operator may need to work to gain public support for introducing UAS into the airport environment.

The DOI Approach to Public Outreach

The DOI is one of the most active users of UAS. The DOI uses UAS for a number of varied missions. To ensure the success of their UAS missions and avoid conflict with the local population, the DOI goes to great lengths to educate the public on their aircraft and activities before and during their operations. The DOI Director of Aviation Services uses scheduled public and town hall meetings and prepared information publications to let people know what their goals are and what types of flying they will do. As an example of the power of public outreach, one of the missions of the DOI is to enforce the laws on illegal dumping of trash and waste. In the Mojave Desert, where the residents are few and value their privacy, DOI representatives made the effort to let the public know they would be flying unmanned aircraft in an effort to locate illegal dumping sites and identify those doing the dumping. This effort happened to support the desire of residents to stop others from dumping trash on their private property. Once the mission, the capabilities, and limitations of the aircraft were laid out, and a face was associated with the drones, the public discovered that flying UAS was a good thing for their community.

Topics for Public Outreach Building and maintaining community support for UAS operations is a continuous process that goes beyond simply giving the public notice of upcoming operations. The community needs to be informed about the organizations that will be conducting the operations, how the flight activities could impact them, and then given the opportunity to ask questions and express any concerns. Using the DOI's approach as an example, a list of topics the airport and UAS operator might present to the public is as follows:

- Define a UAS
  - Explain the history of UAS flying
  - Describe the different types of UAS

- Who is doing the flying
  - Overview and history of the organization
  - Safety record and risk management processes
  - Examples of past missions and their results
- The aircraft and the missions
  - Types of UAS
  - Sensors on board
  - Purpose of the flights
  - Flight routes and restrictions
- Benefits to the community
  - Economic benefits
  - Safety benefits
  - Environmental benefits
- Status of regulation
  - Current regulations
  - Proposed regulations
- The future of UAS
  - Companies involved in the UAS industry
  - Future applications of UAS

The topics are best presented by the UAS operator or by persons experienced in the type of UAS operations to be conducted in order to provide the public with the most accurate information and to completely answer any questions the audience might pose.

Some universities associated with the FAA test sites and others building UAS programs have gone to great lengths to be a source of public information. As an example, the UAS professors from Indiana State University have presented to the local and regional chambers of commerce and several philanthropic organizations, provided numerous press releases to various news agencies, presented at several aviation industry organizations, and continue to give information specifically on educating the public in order to improve UAS acceptance.

Additional Approaches in Presenting UAS to the Public

Regardless of public opinion, there are a few approaches and issues to consider when discussing UAS operations with local officials and citizens.

- Providing *public education* about proposed UAS uses and missions (such as UAS testing, agriculture, photography, and university studies) can have a positive impact. If the public understands what the UAS is doing over or around the community, the likelihood of developing a negative public opinion is lessened. Making presentations at local and regional chambers of commerce events, providing press releases to local and regional newspapers and TV stations, and addressing aviation associations in the state and region can all aid in educating the general public.
- Careful planning of *UAS lost link procedures* and holding points are important operational issues to consider. This specific point was discussed in Chapter 3 as a lesson learned by multiple airports. If a UAS loses the communication links with the pilot or operator, most robust UAS platforms are programmed to perform specific maneuvers until the link is re-established. If those procedures include a holding pattern or returning to a specific area to land, the public should be made aware of this potential so that unnecessary panic and concern can be avoided.
- *Noise considerations* and mitigations are important for the public to understand. While most UAS are actually quieter than manned general aviation aircraft, they may present a different type of sound that the general public is not used to hearing from an aircraft. If this is the case, the public should be made aware of the types of sound they should anticipate in order to head off unwarranted concern or complaints.

- Any *fuel or environmental considerations* of note should also be presented to the public. In most cases, UAS do not operate with exotic or substantially different fuels than manned aircraft. This might be an important point for community awareness in order to alleviate concerns, particularly by environmental groups that may want to restrict UAS growth at the airport.

During the development of the primer, no specific challenges encountered by airports with UAS operations were discovered. This may be attributable to the fact that most of the current UAS operations from airports are taking place in remote locations and therefore, are not in front of larger communities. As UAS become more reliable and the FAA allows operations to occur more frequently from civil airports, the need to educate and communicate with local communities to gain acceptance of UAS will increase.

CHAPTER 5

Regulatory and Community Considerations

A balancing act is ongoing between groups on how quickly the young UAS industry should grow and how it should be regulated. The proponents of rapid UAS growth include the manufacturers, news organizations, and early innovators who see a large potential market with opportunity for a myriad of UAS uses. Those on the opposite side of the fence include individuals and organizations trying to hold the reigns of growth in the name of public safety, flight safety, and the protection of personal privacy.

Federal regulations regarding UAS are centered on safety. Regulations are organized based on the hazards and their associated risks the UAS poses to humans on the ground, in the air to other aircraft, and to assets both manmade and environmental. The ability to mitigate the risks associated with UAS is driving the approach to regulation.

The FAA is working to balance the two sides and ensure safety is always at the forefront. On one hand, the FAA regulators acknowledge that UAS are here to stay. They understand that UAS technology is growing rapidly with great potential to benefit businesses, science, and public service organizations. At present, there are a number of missions, such as wildfire surveillance, agriculture support, and environmental monitoring that can be accomplished more effectively and economically using unmanned aircraft. Regulators understand that their efforts could hold back the growth of businesses, yielding the lead in UAS advances to other, less restrictive nations.

Conversely, the overarching and continuing mission of the FAA is to “provide the safest, most efficient air transportation system in the world” (FAA 2015). They are challenged to safely integrate UAS into the NAS. Establishing airworthiness standards, regulations for airspace use, and rules for operating UAS on and around airports will take time, debate, research, and testing before unmanned aircraft are free to fully integrate with other users of the nation’s airspace and airports. The FAA is charged with managing the safety of this integration knowing that their control efforts will impact the safety of those using aircraft for travel, as well as the safety of those on the ground, especially those living and working near airports.

5.1 Status of UAS Rule Making and Regulation

At the time of primer development, the FAA was establishing rules for UAS. On February 23, 2015, the FAA released a Notice of Proposed Rule Making (NPRM) that when adopted will amend regulations and establish specific rules to allow the operation of small UAS in the NAS. The NPRM can serve as a positive step in expanding the public use of UAS for commercial purposes.

The development of rules and regulations will be supported by the efforts of the national UAS test sites and the research to be conducted by their team members. New standards will also take advantage of the experiences of UAS units in the Department of Defense, NASA research projects, and the programs envisioned for execution by the soon to be established FAA COE for Unmanned Aircraft Systems.

Initial rule making by the FAA will apply to small UAS or aircraft weighing 55 pounds or less that rely on line-of-sight control and communication. The FAA believes this initial regulatory effort will satisfy the bulk of the current demand for UAS use. While the rule making process is proceeding, UAS operators can receive approval for early commercial operations by applying for an exemption under Section 333 of the FAA Modernization and Reform Act of 2012. All of these efforts put the journey toward UAS integration into the NAS well underway.

Regulatory Exemptions Issued In September of 2014, the FAA granted the first regulatory exemptions to six aerial photo and video production companies for use of unmanned systems in their business activities. This is an initial step to allowing the companies to operate UAS in the NAS. United States law requires that any aircraft operation in the NAS be conducted by a certificated and registered aircraft, flown by a licensed pilot, having attained operational approval for the flights. Section 333 of the FAA Modernization and Reform Act (which can be found at https://www.faa.gov/uas/media/Sec_331_336_UAS.pdf) grants the Secretary of Transportation the ability to approve UAS operations in the NAS on a case-by-case basis in lieu of the grant of an airworthiness certificate. This authority is providing early UAS operators opportunities to conduct commercial operations prior to the finalization of the Small UAS Rule. Ultimately, rulemaking will be the main method for authorizing small UAS operations but will take time to complete.

According to the FAA, the Section 333 Exemption process "provides operators who wish to pursue safe and legal entry into the NAS a competitive advantage in the UAS marketplace, thus discouraging illegal operations and improving safety."

Segregating Traffic The proposed rule for small UAS uses the segregation of air traffic as the initial means of ensuring safety of operations. The rule would require UAS operators to fly their aircraft no higher than 500 feet above ground level, at speeds no greater than 100 miles per hour, within the line-of-sight, and only during daylight hours.

Certain portions of the proposed rule will impact airports. The proposed rule would allow small UAS to operate on or within 5 miles of airports (i.e., in Class B, Class C, or Class D airspace or within the lateral boundaries of the surface area of Class E airspace designated for an airport), but the operator must have prior authorization from the ATC facility controlling that airspace. The rule preamble also offers an additional category of small UAS for comment—those weighing less than two kilograms—with a potential designation as micro-UAS. Micro-UAS would not be allowed to operate within 5 miles of an airport at any time.

For larger UAS that require the use of airport facilities, current ATC technologies and UAS sense and avoid systems are not yet ready for the establishment of standards for the inclusion of UAS in the normal airport traffic patterns. Due to the technological gap, along with results found in FAA air traffic simulations highlighting the need for extended downwind travel and wake turbulence avoidance, the FAA is likely to keep UAS segregated from manned aircraft in the name of flight safety, and a desire to not disrupt normal airport operational capacities. As discussed in Chapter 3, successful integration of military UAS with manned aircraft in the airport traffic area has been done successfully. These experiences, along with additional tests and trials anticipated at the UAS test sites, will provide information that may aid the FAA to develop airport operational standards in the future.

Early NAS Integration Testing The FAA is working to identify the potential hazards associated with UAS integration. Hazard identification and the testing of operational processes are ongoing both in FAA simulations, and in flight tests conducted at sites around the country. One such flight test of UAS integration into the NAS is to take place in New Mexico in 2015. The planned test will be conducted from Cannon Air Force Base. Planning is ongoing for 26 UAS to launch from the airfield into the Class D airspace, then transition into Class A airspace where they will fly varied profiles. The flights will involve the MQ-1 Predator and the MQ-9 Reaper. These aircraft will fly profiles as long as two and a half hours, climbing to as high as 18,000 feet and flying up to 150 miles from the airfield. Each UAS will have a chase plane alongside to ensure the safety and visibility of the operations. Tests like it are designed to explore the requirements for full integration of UAS with normal air traffic and to exercise the procedures for lost communications and lost data-link with the UAS.

The FAA and other organizations involved with the national UAS test sites will continue to research the necessary steps toward full integration of UAS into the NAS, and the testing will likely provide UAS operators with more and more opportunities to use the aircraft in new ways. In the near term, the easiest and safest solution is to keep UAS away from the airport pattern and out of Class D airspace. In the future, experience gained in testing and from military UAS flying units will lead to full integration of UAS with manned aircraft.

5.2 Challenges to Effective Regulation

There are a number of challenges that regulators expect to face in the early stages of industry development. A prime challenge is presented by UAS operators with little knowledge or experience in flying, or may choose to fly small UAS regardless of complying with current flight rules and regulations.

Educating UAS Operators and the Public A goal of organizations serious about using UAS for commercial purposes is to ensure unmanned flights are as benign and safe as possible. It benefits UAS businesses when those buying and flying small UAS for private purposes are educated on the proper and safe use of these new aircraft. UAS education will also help gain support and acceptance by members of the public likely to be impacted by UAS operations.

The AUVSI is currently leading a joint effort aimed at educating the public on future, proper, and safe uses of UAS. The "*Know Before You Fly*" campaign started in December of 2014, when the AUVSI, the Academy of Model Aeronautics (AMA), the Small UAV Coalition, and the FAA partnered to provide prospective UAS operators with the information and guidance needed to fly safely and responsibly.

The campaign plans to team with manufacturers and distributors to provide consumers and businesses with the types of information needed *before* flying a UAS. The information is provided through a website, educational videos, point-of-sale materials, and digital and social media campaigns. The "Know Before You Fly" website (http://knowbeforeyoufly.org/) contains pages with information applicable to recreational users, public entities, and business users. It contains contact information, links to additional resources, and printable brochures aimed at enhancing UAS operations. Airport operators can steer stakeholders and members of their communities toward the campaign materials as a starting point for local UAS discussions.

Small UAS Operations at Airports as a Pathway UAS operators interviewed for this primer acknowledged that in the near term the largest percentage of UAS operations and testing outside of the military will involve small aircraft that do not require airport facilities. For the airport operator looking to pave the way toward future UAS integration, involvement with small UAS operators could open doors to the industry. This could be achieved through involvement in the test activities of the selected FAA test sites; or through agreements with small UAS operators for the use of facilities, land, and airspace controlled by the airport. For example, one airport manager who runs an uncontrolled general aviation airport that serves as a reliever for a small hub airport stated that he was in discussions with one national test site, exploring the testing of airspace and manned aircraft integration processes using small UAS. His goal is to use initial testing as a means to learn about the UAS industry and make connections with companies that may become future tenants as the industry grows.

Enforcing the Regulations With swift rulemaking comes the question of enforcement. Given the large numbers of available small UAS and the remote locations where they can be flown, it would likely many regulators to enforce the rules. Given the growing interest in UAS and still widely held civic safety and privacy concerns, one opinion is that the public will become the enforcers of the regulations. As more and more UAS fly, and the flying increases in frequency in populated areas, it is possible that people may become concerned with the activity and call police or the local airport to report the UAS operations they see.

Airport managers and operators can be a positive force in ensuring safety UAS operations by staying abreast of the rulemaking process and UAS related stories. The FAA regularly posts news releases relating to the status of UAS regulation on the FAA website, and news on advancing UAS technologies can be found on the Internet. Airport operators should be ready to respond to questions and concerns from the public about unmanned aircraft. Airports with UAS experience have had to respond to calls from community members who have seen small aircraft flying near or over their homes. The calls typically come from people with little knowledge of the types and uses of the aircraft, and then turned to the only aviation source of information they know: the local airport.

It will benefit airport managers to stay in close contact with their local FAA representative to ensure they receive the latest information on UAS activity and regulations. Interaction with FAA representatives can provide airports with up-to-date guidance from the regulators, and facilitate communications between the FAA representatives and FAA headquarters regarding UAS issues.

5.3 UAS and Model Aircraft—Different Approaches

An area that may cause a bit of confusion in the early days of UAS regulation is determining which aircraft will fall under the proposed small UAS rule and which aircraft will fall under the current regulations for model aircraft. Model aircraft are in fact UAS. The discussions center on where the two similar aviation segments meet or diverge.

Until the time when the small UAS rule is finalized, UAS operators must either operate their aircraft as model aircraft or receive authorization to fly in the NAS. According to the FAA regulations, model aircraft operations are for hobby or recreational uses only. As an example, using a UAS to take photos for your personal use is recreational; using the same device to take photographs or videos for compensation or sale to another individual would be considered a non-recreational, or a commercial operation. The use of a photo or video taken with a UAS in an ancillary use, such as advertising for a business, is considered a commercial operation even if the photo or video is not sold.

The statutory limits for model aircraft operations are outlined in Section 336 of the FAA Modernization and Reform Act of 2012 (Public Law 112-95). UAS operators who fly within the scope of these parameters do not require FAA permission to fly. Any flight outside these parameters, including intended commercial use of a UAS, requires the operator to obtain either a Section 333 exemption or an airworthiness certificate, and also obtain a COA to operate in the NAS. (Details on gaining these approvals can be found on the FAA website at http://www.faa.gov/uas/civil_operations/.)

The FAA developed a fact sheet that gives an overview of the UAS for public information. The fact sheet on UAS provides summaries on such topics as the safety goals of the FAA; public UAS, civil UAS, and model aircraft; UAS definitions; and overviews of the national UAS test sites. The UAS fact sheet can be found at https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=14153. It is outside of the FAA UAS pages but is a resource airports may want to use when addressing UAS questions from their communities.

5.4 COA Application and Considerations

At present, flying UAS in the NAS requires the application for and the FAA approval of a COA. The FAA defines a COA as follows:

> COA is an authorization issued by the air traffic organization to an operator for a specific UAS activity. After a complete application is submitted, FAA conducts a comprehensive operational and technical review. If necessary, provisions or limitations may be imposed as part of the approval to ensure the UAS can operate safely with other airspace users. In most cases, FAA will provide a formal response within 60 days from the time a completed application is submitted.
>
> The COA allows an operator to use a defined block of airspace and includes special provisions unique to the proposed operation. For instance, a COA may require flying only under visual flight rules (VFR) and/or only during daylight hours. COAs usually are issued for a specific period—up to two years in many cases. (FAA 2014a)

Airports may play an active role, a peripheral role, or may have no role at all in the COA application process. It is up to the discretion of the airport, but there are benefits to being involved in the process. The responsibility for gaining COA approval falls to the UAS operator. The process is made easier if the operator reaches out to the other stakeholders involved in the proposed UAS operations (ATC, airport management) for assistance and support of the request. As UAS integration looks to be on the airport's horizon, the airport can work with the UAS operator as an ally and ensure the airport's interests are part of the process. As an example discussed in Chapter 3 of the primer, the GTR's active involvement in the development of a COA with a UAS tenant, Stark Aerospace, elevated the need to clear the airport's Class D airspace during UAS operations. By planning and gaining approval for a division of airspace to ensure separation of UAS from manned aircraft, the airport was able to avoid the potential for commercial air traffic disruptions and decreases in airport capacity.

The COA process can be time consuming. For the UAS operator, those with COA process experience have found that once applicants become familiar with the process, applying becomes simpler and faster. In addition, as the approval authority the FAA also needs time to process the applications. Over the years, time needed for the FAA approval process has decreased.

COA applications can now be submitted online via the FAA website. The link to the application pages can be found on the FAA UAS COA webpage: http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/systemops/aaim/organizations/uas/coa/.

The UAS COA Online System requires that the user establish an account with the FAA. The application process is user name and password protected. While the primary users of this system

Chapter 1
Chapter 2
Chapter 3
Chapter 4
Chapter 5
Chapter 6
Chapter 7
Chapter 8
Chapter 9
Appendices

will be the UAS operators serving as the applicant, the airport operator can work with the applicant to ensure the information on the airport is accurate when submitted.

Examples of Approved COAs Well over 500 COAs have been approved by the FAA for UAS operations in the NAS. A number of examples of the approved COAs are available as the result of Freedom of Information Act requests. As of the date of primer development, 79 example COAs are posted to the FAA website at http://www.faa.gov/uas/public_operations/foia_responses/.

The example COAs can be downloaded as zip files. Each example includes a number of files that provide information on such aspects of UAS operations as:

- Aircraft system descriptions
- Control station descriptions
- Communication modes
- Emergency procedures
- Maps of the areas of operations
- Lost communications procedures

Registration of UAS UAS flown in the NAS, outside of those operated by the military, currently require the operator to register their aircraft with the FAA. In an example letter to COA holders dated November 5, 2014, the FAA reminds the operator and provides:

> . . . information regarding the statutory requirement to register aircraft and includes details on the registration process and marking. If you need to register aircraft, you will have 45 days from the date of this letter to submit an Aircraft Registration Application to the FAA. (FAA 2014b)

The example letter can be found on the FAA UAS site at http://www.faa.gov/uas/regulations_policies/media/Registration_letter.pdf.

As the airport community looks to actively recruit UAS operators to their facility, having someone on the airport staff with COA process knowledge or experience to act as the airport COA point of contact might be attractive to potential tenants. The FAA and all stakeholders actively involved in the UAS industry are trying to make the process for UAS operations approval in the NAS more streamlined. Airports are important stakeholders and can be a positive influence on the process.

5.5 Grant Assurances

Airport operators should understand their obligations with regard to grants and how UAS operations might impact them. At the time of primer development, airport operators who have been or are now actively receiving grant funds, AIP grant funds in particular, should treat a new UAS operator as they would any new operator or tenant. The same rigor should be applied to their entry onto the airport to ensure no grant assurances are broken, thus placing the airport in a possible repayment or loss of funds situation. For airport operators less familiar with grant assurances and how they work, the FAA provides an explanation on the FAA's website on the grant assurances (Obligations) page:

> When airport owners or sponsors, planning agencies, or other organizations accept funds from FAA-administered airport financial assistance programs, they must agree to certain obligations (or assurances). These obligations require the recipients to maintain and operate their facilities safely and efficiently and in accordance with specified conditions. The assurances may be attached to the application or the grant for federal assistance and become part of the final grant offer or in restrictive covenants to property deeds. The duration of these obligations depends on the type of recipient, the useful life of the facility being developed, and other conditions stipulated in the assurances. (FAA 2014c)

Specific resources for grant information are contained in Appendix A, Section A-2.

Interviews with airport operators who have UAS experience revealed the belief that UAS facility development will ultimately become AIP eligible. There is UAS industry-wide support to expeditiously work toward commercial UAS access to the NAS. A key to making this happen (outside of regulation) is supporting smaller airports that might realize UAS opportunities before larger, more established airports. Smaller airports are less likely to have facilities or funds available to provide a UAS operator what they need to be successful. Yet, smaller airports are more likely to have UAS friendly airspace that may be more attractive to the UAS operator. How grant assurances can aid airports in supporting future UAS operations is something airport operators should watch closely.

5.6 Economic Development

The UAS industry is still very new and few specific civil examples of economic development directly attributable to UAS were available at the time of the primer development. There are, however, examples from the U.S. military. The DOD has made considerable investments in UAS. In many cases, military UAS operators are utilizing existing airfield facilities. However, the military and joint-use airports interviewed for the primer voiced a consistent theme: UAS operations of any size require some investment in facilities to support the systems and personnel. Maintenance, storage, and operational facilities have all been constructed as UAS operations expand and as new systems are introduced. In some cases new buildings or ramps were constructed, or old ones were repurposed after refurbishment. The investments provided local jobs and material sales for periods of time. The most visible economic advances in the communities were related to UAS facility construction activities.

The universities interviewed for the primer did not identify investments needed at their local airports to support current UAS activities. Kansas State University (KSU) owns and maintains two hangars with a through the fence operation at Salina Regional Airport (SLN) in Kansas. The UAS that KSU operates are small (less than 55 pounds) and are all maintained at existing campus facilities. Two KSU hangars support the rest of the KSU aviation school and are separate from UAS operations. The situation at Indiana State University (ISU) is a similar to that at KSU. No investment in facilities is currently needed or planned. However, ISU is assisting the local airport, Terre Haute International Airport (HUF), with a COA application to support ISU testing. This effort is providing HUF with valuable experience in the UAS approval process.

The opportunities for airport and community economic development will come from long-term, sustainable UAS operations. Airport operators interviewed believe that ultimately UAS ground control stations, data storage capabilities, and robust communication links will be needed for UAS growth to occur. They see these types of investments as opportunities for airports to attract UAS operators. By attracting UAS operators, they see the need for support services and professional jobs in the community growing. The Nevada National UAS Test Site was established with over 40 general aviation airports on the application. None of them have active towers and none of the airports are considered busy. The airport managers who were approached during the test site application process all agreed to participate for a variety of reasons, but one common theme persisted—they all believed it would help their small communities with economic development. An airport manager interviewed during research for the primer explained that having as few as two additional people working at the airport in support of UAS operations would still be two more people contributing to the economy of the community. It is this grass roots approach to UAS economic development that will ultimately aid and accelerate the public acceptance of UAS.

5.7 Environmental Impacts

At this point in the UAS industry development, information regarding specific environmental concerns and impacts is minimal. The U.S. military has the most experience and information with regard to UAS and how they have been introduced into their system. In discussions with members of the military familiar with UAS operations, no special UAS environmental concerns were raised beyond the issues normal for manned aircraft operation. In general, no new exotic fuels are currently being used, and UAS payloads are data collection or communication focused. The civilian operators and universities interviewed also did not identify any overarching environmental concerns.

To date, UAS have been introduced into air transportation using similar propulsion methods and airframe materials that most manned aircraft have been using for decades. The UAS environmental impacts that may impact airport operators are similar or identical to those of any new tenant or operator. Basic plans for such issues as fuel containment, stormwater discharge, air pollution, and noise pollution should suffice in addressing current UAS operations.

Fuels and Payloads Future UAS operations do not appear to be headed toward completely new fuels, payloads, or materials. It is probable that UAS in the future will rely upon advanced fuels for propulsive energy. Research is underway to explore such UAS power sources as solar cells, bio-fuels, and hydrogen fuel cells. The Boeing Corporation is working on a high altitude, long-duration UAS that operates on diesel engines which use hydrogen as their source of fuel. Georgia Institute of Technology (Georgia Tech) is researching and has flown a UAS utilizing a fuel cell of compressed hydrogen. Initially these sources of power are expected to be confined to very small UAS. As technology advances, airports will likely need to consider incorporation of the logistics necessary to power new aircraft with fuels other than conventional jet fuel and aviation gasoline. At present these concepts do not present any specific, near term airport environmental concerns.

Airport operators are encouraged to include environmental issues on their list of topics to discuss with UAS operators prior to commencing operations. There is a checklist for UAS facility requirements provided in Appendix C, Section C-2 for reference.

5.8 Land Use Compatibility

The limiting factor with regard to UAS operations is the airspace and the restrictions placed on that airspace. UAS operations will most likely fall into one of two categories related to land use; either the UAS operator will require facilities and access to the airfield (hangars, ramps, movement area), or they will be able to operate independently of these facilities. If the UAS operator does not need use of the airfield facilities, then use of property near the airport may become an issue. UAS operators can operate from property not owned by an airport; if they don't violate airspace restrictions and are outside of 5 miles from the airport boundary, then coordination with the airport is not required. None of the discussions conducted in the development of this primer yielded any land-use compatibility issues.

Long-range planning for land use and UAS is a slightly different matter. Airport operators are encouraged to take a master planning approach in creating a vision for future UAS operations. Land-use planning is an important aspect of this approach. Long-range planning about where permanent ground based control stations might be located, as well as where to place storage and maintenance facilities that may require airfield access might be prudent approaches for those airports looking to attract UAS operators.

UAS Impacts and Airport Grants For those airports that receive FAA grant funds, it will be important for the airport management to ensure there are no land-use issues that violate the grant assurances. Airport operators are encouraged to have a discussion with their FAA Airports ADO prior to executing agreements with UAS operators for airport facilities or property. The property itself might be encumbered in such a way that UAS use might not be permitted. This is highly unlikely, however, given that the FAA and the NTSB have determined that UAS are aircraft. Moreover, local zoning laws and local restrictions might prohibit such activity. It will be up to the airport management to investigate and ensure UAS operations do not violate any restrictions. Land-use issues are listed on the UAS checklist in Appendix C for reference.

CHAPTER 6

UAS Infrastructure Considerations

UAS infrastructure needs are driven by the type of UAS, its purpose, and the support services required. Some UAS may require little support from the airport other than a piece of ground from which to fly, while other systems need specialized facilities and procedures. Some airports may have all the UAS infrastructure needs in place while other airports might require modification to support new UAS activities. There are many aspects of UAS operations that are similar or identical to manned aircraft. Airport operators are encouraged to understand the infrastructure needs of UAS operators, putting themselves in a better position to attract UAS business to the airport. See Sections 4.2 and 4.3 for potential revenue streams and infrastructure needs and costs.

6.1 UAS Facility Requirements

The facility requirements for the wide variety of unmanned systems vary by size and system complexity. Small UAS may not have any airport facility requirements. Larger UAS, as discussed in previous sections, will require more facilities similar to manned aircraft operations. Hangar space, ramp space, runways, taxiways, along with ground control stations, data storage, and communication capabilities may all be necessary. Much like any new airport tenant, the airport operator should plan for UAS facility needs by researching the requirements, and determining how existing facilities can accommodate the needs or identify and plan for new facilities.

Airport—UAS Operator Discussion Checklist Airport operators may benefit from using a checklist for discussions with UAS operators in order to understand their needs. Such a checklist might include the following:

- Communication requirements to include radio frequencies
- Data collection and storage
- Hangar space or aircraft storage space
- Ramp space and aircraft preparation areas
- Runway use and length requirements (to include time required on the runway prior to takeoff)
- Launch areas (if different from a runway)
- Recovery areas (if different from a runway)
- Ground control station space (office space or mobile office space)
- Ground support equipment area (equipment space necessary within close proximity to the UAS launch site or runway end)
- Fuel type and storage requirements
- Maintenance and parts storage areas
- Classroom and briefing space

The UAS mission or purpose will drive the equipment the UAS must lift (cameras, recorders, weapons, communication systems, fuel, and engine or motor capacity), which in turn will drive the size of the UAS. Some of these sub-systems may require specialized handling as well. In order to understand the facility requirements, a complete picture of the UAS is needed.

6.2 Launch and Recovery Systems and Requirements

Launch and recovery systems are also tied to the size and function of the UAS. Larger UAS such as the Predator and Global Hawk are runway dependent for their takeoffs and landings. Small UAS are or often hand-launched or utilize a small catapult to get them airborne. Recovery of small UAS can be accomplished by a vertical landing, a skid landing onto relatively flat ground, or the use of a recovery net. Regardless of the mode, all UAS may find that an airport is the right place from which to operate.

Airport operators should expect UAS which require the use of a runway to be able to operate on most general aviation airport runways. The airport's Airport Reference Code (ARC) can be used to determine if larger UAS are compatible with the physical airfield itself. The ARC is based on the largest aircraft operating (500 annual operations) at a particular airport and sets the standards for pavement and safety area geometry.

As noted in Chapter 4 of the primer, an interesting aspect of some UAS which takeoff automatically is the amount of time required on the runway prior to takeoff. An example is the U.S. Army Grey Eagle. The Grey Eagle is considered a tactical UAS which uses a runway for takeoff and lands in the same location from which it departed. It can land via a skid landing or utilize the runway surface. In order for the Grey Eagle to be able to takeoff automatically, it requires up to two minutes sitting "lined up" on the runway in order to synchronize the global positioning system (GPS) coordinates. This type of operational requirement means the runway is effectively closed for those two minutes. This may not be a problem for some general aviation airports; however, for airports with scheduled air carrier service it will affect airport capacity and poses a hazardous condition as the aircraft sits on the runway.

6.3 UAS Runways

The runway requirements for UAS will ultimately depend on the type and operating capability of UAS at a particular airport. UAS runway use is something to be assessed in planning. While dedicating specific runways for UAS only use may be impractical for most airports, given requirements for systems like the Grey Eagle, there are advantages that should be considered. The limiting factors for UAS operations when conducted together with manned aircraft operations relate to ATC and airspace classification. The COA and the Airworthiness Certification processes deal primarily with airspace considerations and will always error on the side of safety. To date, UAS operations are segregated or separated from manned aircraft operations whenever possible. With few exceptions, UAS flights are not allowed to traverse the Class D airspace while manned aircraft are operating in the aircraft traffic control pattern and vice versa. Further, civil UAS operations are not allowed at night. Because of these restrictions, in most cases dedicated UAS runways would not be beneficial; having dedicated UAS runways would not change the airspace and the way in which it is controlled.

Dedicated runways are also not typically available at the types of airports that have UAS operations. The most common UAS operations on civil airports are occurring at joint-use airports where military operations are supported alongside civil aircraft operations. At these airports the airfield becomes joint-use to take advantage of the economies of scale making operations more affordable for both parties. In many cases the civil airport operator and the military airport operator exchange services for use of the facilities. Neither side has the luxury of a dedicated runway being available. This is not to say, that one runway could not be identified as the primary UAS runway when UAS operations are conducted and made available for manned aircraft operations when no UAS are flying.

Wind Considerations Prevailing wind considerations and other airport operating factors should also be considered when determining the runways used for UAS operations. Wind limitations for the aircraft are considered by the FAA during the COA application process and need to be planned prior to the application being submitted.

Takeoff and Landing Options Airport operators should discuss all takeoff and landing options with the UAS operators to maximize the airport's operational capabilities. Many unmanned systems will present opportunities to take off and land from taxiways, runways or portions of runways closed to manned aircraft, or even level grassy areas on the airport. These options should be assessed for their hazards and associated risks to ensure safety of airport operations.

The near term growth of runway dependent UAS will likely occur at smaller airports with limited commercial air carrier service. Advantages of UAS operations at small airports include less restrictive airspace (most likely), a less congested surface environment, perhaps easier access to special use airspace, and even ease of access provided by less restrictive security requirements. Many general aviation airports will not have additional airfield capacity issues and may be able to dedicate added resources to UAS operations. The most likely airport situation is that UAS will co-exist with manned aircraft on the airport, on the runways and taxiways, and in the airspace to the extent the FAA determines an acceptable level of safety is provided.

CHAPTER 7

UAS Operational Considerations

When the introduction of UAS into the environment of an airport is considered, an important question that must be answered by airport managers is how the unmanned aircraft will impact current airport operations and procedures. In general, airports having experience with UAS indicate that unmanned aircraft operations can co-exist with manned aircraft on civilian airports with relative ease. This chapter discusses some of the aspects of UAS operations that should be considered prior to introducing UAS activities to the airport.

7.1 Segregation of UAS Operations

The segregation of UAS and manned aircraft is typical when UAS operations are integrated with civil aircraft. In the early stages of UAS development this was not the case. During the initial integration of UAS operations at the VCV, UAS and manned civil aircraft were allowed to occupy the same airspace, operate together in the airport traffic pattern, and taxi about the airfield simultaneously. This was accomplished without major incidents or accidents between aircraft. As UAS activities grew across the nation and the FAA instituted restrictions on UAS operations, the segregation of manned and unmanned aircraft was mandated at civil airports, along with limiting UAS flights to daytime only. These changes came about when the institution of the requirement for an approved COA became the norm and the FAA reviewed all COA requests. These additional restrictions were deemed necessary in order to provide an acceptable level of safety.

While complete segregation of UAS and manned aircraft operations might be possible at most towered general aviation airports, it can be problematic at non-towered airports. Even though an operating restriction might be put in place through a COA, the enforceability of the separation requirement rests primarily with the UAS operators given their size and the challenge for pilots of manned aircraft to see them. At general aviation airports, it will be important for the UAS operator to communicate with other airport users via Unicom or Multicom radio frequencies. Other airport users will need to know that a UAS is operating at the airport and ensure separation themselves.

This situation will likely cause operational limitations and capacity issues for the airport. Understanding and communicating any restrictions placed on manned aircraft operations to the tenants based at the airport, and to known transient users, will be important for airport operators. This will allow airport tenants and known transient aircraft pilots to adjust schedules and flight plans accordingly.

7.2 Similarities and Differences Between Manned and Unmanned Aircraft Operations

In general, large, unmanned systems can require the use of runways and taxiways and operate in a manner similar to manned aircraft. Many large UAS move about the airport like a manned aircraft, they require ramp space and hangar space, and fly in the same airspace. Unlike manned aircraft, some UAS need a ground control facility from which the pilot communicates with and flies the aircraft. A number of UAS types also require more direct monitoring and control while in the movement area or flying in the airspace in order to maintain separation with other aircraft.

Smaller UAS that do not require the use of movement area surfaces will require a different type of oversight by the airport should they operate on airport property. Hand-launched UAS might operate from remote sections of the airport or from fields and areas away from the airport runways. As an example, at the VCV the National Guard units not only fly large UAS like the MQ-1 Predator and MQ-9 Reaper, units also train with land-launched UAS in a separate area of the airport in support of urban warfare training. These two types of operations are planned for and segregated by the UAS operators and ATC during airport operations scheduling meetings.

UAS That Require Aircraft Movement Areas

Larger UAS that require use of a runway and taxiway can use the same movement areas as a manned aircraft. The most notable differences between large UAS and manned aircraft are the methods of communication and the separation required between aircraft.

A larger UAS that operates beyond line-of-sight is flown by a pilot from a remote fixed ground control station (FGCS) as opposed to the pilot in the cockpit of the aircraft. In general, UAS that utilize movement areas use the same means of communication as manned aircraft. The pilot communicates with ATC and with other aircraft on the same radio frequencies as other aircraft at the airport. The difference is that the pilot's ability to see traffic on the ground and in the air is a function of the sensors on the UAS. In some cases, when a UAS approaches an intersection on the taxiway, the pilot may stop the aircraft and scan the area with the aircraft's optical sensor. The margin of safety is recovered in the form of increased separation. In other cases, the UAS might be monitored or escorted by an observer to increase the margin of safety.

Current state of regulation and safety requires that UAS must also maintain a wider separation between themselves and manned aircraft. This approach will likely remain the primary FAA approach to ensure safe operations until such time that UAS safety and self-contained separation capabilities can be determined to be reliable enough to allow open access to the NAS.

Operational Limitations UAS that utilize aircraft movement areas in the same fashion as manned aircraft may have certain operational limits placed upon them to ensure the safety of operations. For example, the airport and ATC may require the UAS operator to provide a wider margin of separation from other UAS and manned aircraft during taxi, takeoff, and landing to minimize conflicts. Some operational limitations followed at airports operating UAS include:

- A UAS and another aircraft (UAS or manned) are not allowed in the airport's approach or departure pattern at the same time. Standoff distances are based on the environmental conditions, such as weather in the area and visibility.
- A UAS and another aircraft are not allowed on the same movement area simultaneously.

- The taxi route to and from the runway must be completely clear of aircraft prior to the UAS going to or from the runway and ramp area.
- UAS are not allowed to operate at night. This restriction might be based upon a lack of ATC after midnight while general aviation and cargo aircraft continue to fly.
- Airspace separation is widened based on environmental conditions.

Requirements such as these can be placed upon unmanned aircraft by the FAA. The limitations tend toward the conservative side of operational safety, which is understandable at this point in the growth of UAS activity. The limitations are not typically based upon aircraft limitations or the actual operational capabilities of the aircraft.

Safety Margins The need for a wider margin of safety also comes from the potential for lost link situations when the UAS suddenly becomes disconnected from its pilot-in-command. This situation must be planned for and built into the way in which UAS are controlled. At airports without ATC services, these margins of safety are even more critical and can require significant planning and contingency plan development on the part of the UAS operator, the FAA, and the airport operator. Separation of aircraft is a key factor to managing some of the inherent safety risks associated with UAS.

Operational speeds of UAS that require the use of movement areas are very similar to general aviation aircraft. Larger jet powered UAS (such as the Global Hawk) taxi at speeds similar to a small business jet or turboprop aircraft. Because they travel at speeds similar to like-sized manned aircraft, the typical limiting factor between UAS and a manned aircraft is the communication required to operate the UAS safely. Wider separation is used to ensure safe operation, something that airport operators need to understand so that they can plan for the potential reduction in airfield capacity.

7.3 Training of Airport Personnel

The training of airport personnel on UAS and UAS operations on or near the airport is dependent on the type of UAS. At this point in the evolution of UAS integration into the NAS, the need for extensive or UAS specific training has not been necessary. In general, airport personnel, especially those associated with emergency response may benefit from familiarization training with the UAS that is going to operate on or near the airport. Currently, UAS are not using exotic fuels or new structural material that would demand specialized training for response teams. Thus, general familiarization with the systems being introduced to the airport is likely all that is necessary. Examples include:

- Fuel and fuel tank placement
- Fuel shut off valve
- Onboard fire suppression systems
- Control systems (onboard computers)
- Communication devices
- Payload access
- Operational characteristics

Training for Airport Personnel at VCV A specific example of airport personnel training came from the VCV. At VCV, airport ARFF personnel went through a familiarization on the UAS itself, the ground crews, and the operators. The familiarization was intended to make the ARFF personnel aware of the issues listed earlier so that in the event of an emergency response the ARFF personnel will have a better understanding of how response situations might proceed.

Airport personnel should also be made aware of stationary communication systems and operating systems. The location of the FGCS and any support utilities should be included in the familiarization.

In general, airport personnel should treat the UAS as they would any new tenant or aircraft operator. New equipment and new requirements that differ from common aircraft operations at the airport should be noted and understood.

In addition to the physical differences of the aircraft and facilities, airport personnel should also be made aware of any communication requirements for the UAS. Airport personnel should understand any potential impacts to locally used radio frequencies, microwave links, or other communication systems. The airport staff should understand any additional data collection and storage requirements. These requirements will depend upon system tasks. For example, if the UAS is intended to photograph, map, chart, and otherwise collect information, special airport considerations may need to be addressed regarding the data capacity and storage the airport has available.

7.4 Airport Certification Impacts and Requirements

Research for the primer did not identify any impacts associated with UAS on airport certification. The introduction of UAS into or near a certified airport does not impact its certification status. The impact of introducing UAS is similar to that of any other new tenant or aircraft operator. The airport operators should ensure they continue meeting all applicable regulations and standards during and after UAS introduction.

14 CFR Part 139 certificated airports have a well-documented process for certification and compliance. General aviation airports, also classified within the National Plan of Integrated Airport Systems (NPIAS), have a set of standards they are required to meet. All 14 CFR Part 139 certificated airports are included in the NPIAS as well. All NPIAS airports are considered significant contributors to national air transportation and are eligible to receive federal AIP funds. In receiving these funds, the airport operator must meet certain obligations and standards regarding the administration of the airport and the safety of the facilities. Section 5.5 contains additional information about grant assurances.

7.5 ATC Operations and Coordination with Airport Operations

ATC personnel with UAS control experience have not identified any specific and consistent issues that impact airport operations or the ability to fly UAS in conjunction with manned aircraft. Airports with UAS operational experience, including VCV, MHK in Kansas, and GRK in Texas, have developed some fundamental coordination procedures that are being used to handle the differences between UAS and manned aircraft. ATC personnel are, for the most part at these airports, doing much of the coordinating with the UAS operators due to the separation and segregation requirements currently associated with UAS. The following are operational examples from select airport operators and ATC personnel.

Southern California Logistics Airport

Airport personnel at VCV are not routinely notified when UAS operations are conducted on the airport. During the early stages of UAS integration, airport personnel became familiar with the systems and their operation. With the large experience base at VCV, there is no longer a need for special coordination for UAS operations unless there is an emergency or special request outside of accepted operations. ATC personnel coordinate directly with the UAS operators on scheduling and flight plans, as well as in the airport pattern for landings and takeoffs for segregation and separation between UAS and manned aircraft.

- Prior to a COA being put in place, the VCV ATC would allow one UAS in the Class D airspace with manned aircraft. Following the requirement for a COA, UAS and manned aircraft are no longer allowed to operate simultaneously. If a UAS is in the Class D airspace, manned aircraft are not allowed in and vice versa.
- The VCV COA does allow for night UAS operations in conjunction with manned aircraft operations. However, the Class D airspace can be designated as "sterilized" thus allowing UAS flying only. If a manned aircraft needs to access the airport at night, all UAS are removed from the airspace.
- VCV ATC prioritizes general aviation and civil aircraft (such as large commercial aircraft using the airport's maintenance, repair, and overhaul services) ahead of UAS.
- VCV ATC adapt their procedures to accommodate the added time required for UAS ground operations and for taxi to and from the runway and ramp areas, as compared to manned aircraft.

Manhattan Regional Airport (MHK)

- MHK is in close proximity to Marshall Army Airfield where the Army flies the MQ-1C Grey Eagle. The ATC at MHK ensures that UAS operations coming from Marshall Army Airfield do not impact the commercial flights into and out of MHK. Both the Army and the MHK management felt it was very important to ensure coordination processes between the facilities were in place to deal with airspace issues early in the process of UAS introduction.
- One airport operational issue discovered during early UAS operations at Marshall Army Airfield was the difference in communications terminology between the UAS operators and the ATC in the tower. Some UAS require an extended period of time on the runway prior to takeoff. The Grey Eagle takes off automatically. Because it requires GPS synchronization prior to departure, it needs to "sit" on the runway threshold for up to 2 minutes prior to starting its takeoff roll. Early in Grey Eagle operations, the UAS operators defined 2 minutes as a "short delay" on the runway, as compared to a few seconds being the definition of a "short delay" used by the tower controllers. Thus, coordination between the airport, UAS operators, and the ATC on common terminology is important for operational continuity.
- At Marshall Army Airfield, Grey Eagle operations require support equipment to be in close proximity to the runway end when launching the aircraft. This equipment is considered an obstruction and therefore the runway becomes unusable until the aircraft has departed and the equipment is removed. While this requirement does not impact operations at the Marshall Army Airfield since the Army controls the airspace, the facilities, and the aircraft, it does require coordination with ATC. Operations of this sort would have a major impact to a civil airport. Operational requirements that impact runway availability require planning and coordination with the airport.

Killeen-Fort Hood Regional Airport (GRK)

- GRK is a military airfield but has scheduled commercial service by three airlines. The Army operates the RQ-5 Hunter and the MQ-1C Grey Eagle UAS from GRK. The key to the success of their operations is continuous coordination and information sharing between the UAS operators, ATC, and the airfield operations supervisors.
- The controllers at GRK point to integrated planning on lost link or lost communications procedures and an acceptable lost link loiter point for the UAS as keys to success. All stakeholders were involved in this planning, including members of the local community, so that the selected location was away from population and infrastructure, making property damage and injury highly unlikely.

- GRK only uses NOTAM to inform other flying organizations and pilots of upcoming UAS operations. There is no additional coordination done with the commercial air carriers. This method of coordination ensures that information on UAS operations is found in only one place, thus minimizing confusion and duplication.

As illustrated with these experienced airports, the coordination necessary between ATC and the airport operator is dependent upon the type of UAS, the airspace, and the existing manned aircraft traffic at the airport. A concerted effort needs to take place to ensure that all known issues with the UAS operation are discussed by and with all interested parties.

7.6 UAS Communications and Electromagnetic Spectrum Related Issues

Communications for UAS operations is the most important aspect. If a manned aircraft loses communication with the ground, the pilot still has the skills and the training to operate the aircraft safely. Unless fully autonomous operations are approved, the UAS pilot must normally have a link to control the aircraft at all times.

UAS communication requirements vary widely and are based upon the aircraft's purpose and the capabilities. Some UAS operate in an automated mode until they reach an established altitude following takeoff. Others require human control during takeoff and landing, and fly in an automated mode during the rest of the operation. Still other aircraft takeoff, maneuver, and land automatically with operator intervention required only when deviations to the planned route of flight are required, say for weather or for traffic deconfliction. Most UAS, however, require constant control and therefore communication with a human throughout the operation.

Radio Frequencies Radio frequencies are commonly used to communicate with most small UAS. The power used to "push" these radio signals is not usually strong enough to disrupt other vehicles or services in the area. However, research conducted at the North Dakota University UAS Test Site has shown that in some cases systems were pushing radio waves strong enough to disrupt some ground based operations in Canada. It is imperative for the UAS operator and the airport to understand the possible communication issues prior to commencing operations. Airport operators are advised to have a communication checklist established that will aid in determining if potential issues with communication frequencies exist.

Radio frequencies and the power by which they are pushed to the UAS are issues that are considered during the COA and Airworthiness Certification processes. According to the FAA's Order 8900.1 (*Flight Standards Information Management System—FSIMS)*, Volume 16, Chapter 5, Section 3, the following guidance regarding spectrum authorization is offered:

1. Every UAS proponent must have the appropriate National Telecommunications and Information Administration (NTIA) or Federal Communications Commission (FCC) authorization/approval to transmit on the radio frequencies (RF) used for UAS uplink and downlink of control, telemetry, and payload information.
2. Non-federal public agencies, such as universities and state/local law enforcement, and all civil UAS proponents generally require a license from the FAA as authorization to transmit on frequencies other than those in the unlicensed bands [900 megahertz (MHz), 2.4 gigahertz (GHz), and 5.8 GHz]. This generally will be in the form of an experimental radio license or a special temporary authority (STA) issued by the FCC. Non-federal public agencies and civil UAS proponents that operate systems using frequencies assigned to the federal government (e.g., the DOD) must demonstrate they have the proper authorization through FCC-issued documentation.

3. DOD agencies will typically demonstrate UAS spectrum authorization through an STA issued by NTIA or a frequency assignment in the NTIA-administered Government Master File (GMF). Authorizations issued under Title 47 of the Code of Federal Regulations (47 CFR) part 300, in the NTIA Manual, Chapter 7, paragraph 7.11, Use of Frequencies by Certain Experimental Stations, are not appropriate for UAS operations.
4. Federal public agencies other than DOD, such as NASA, U.S. Coast Guard (USCG), and U.S. Customs and Border Protection (USCBP), also need an STA issued by NTIA or a frequency assignment in the NTIA-administered GMF. This is especially important for systems designed to operate on frequencies assigned to DOD.

Airport operators who have an interest in UAS operations being conducted at their airport should be aware of potential radio frequency issues. These may become limiting factors in UAS operations on or near the airport. If an airport operator has a working knowledge of the issues, they will better prepare the UAS operator for the COA application process and mitigate any communications issues.

CHAPTER 8

UAS Safety and Security

Introducing UAS into the airport environment will introduce additional levels of safety and security risk. This is always the case when introducing new systems to the airport. The current application and approval processes for UAS are aimed at managing these risks, protecting the operators and aviation assets, and ensuring the safety of communities surrounding the airport. As discussed earlier in the primer, the process for UAS to access the NAS requires a COA to be issued and the receipt of an airworthiness certificate on the specific UAS. This FAA process includes a risk assessment with regard to the safe operation of the UAS and its potential impact on the NAS.

Airport security issues are directly tied to the UAS itself and its mission or function. UAS operators might require special security measures if the information they gather is highly confidential or if the UAS itself is experimental and proprietary designs or information need to be protected.

This chapter addresses these issues in more detail, along with safety, emergency response, and ARFF.

8.1 Safety Management System (SMS) Development for UAS

The pending requirement for Part 139 certificated airports to develop and implement a SMS has been well publicized and valuable guidance is available on the topic. Several resource links are provided in Appendix D for reference. Commercial air carriers are now required to develop and implement an SMS to help improve safety performance and better protect the flying public. As the aviation industry moves toward the systematic approach to managing safety risks, it makes sense for organizations looking to introduce UAS have sound safety programs and plans in place.

The FAA's SMS processes for risk management are well documented and have been in use for almost a decade by the air traffic and aviation safety lines of business. The COA application process and airworthiness certification process support the internal FAA SMS and are intended to provide enough information about the UAS so that risk informed decisions can be made relating to UAS operations approval. That said, because the FAA will continue to use SMS to identify hazardous conditions and mitigate their associated risks, airport operators will likely benefit from an understanding of how UAS operations can and should be viewed through the SMS lens.

SMS Illustration—Maintaining Aircraft Separation

As discussed in earlier sections, segregation and separation of UAS from manned aircraft operations is currently the general approach to mitigating most of the aircraft collision risks. Until UAS technology has evolved to fully demonstrate the ability to see and avoid through sense and avoid methods, the primary mitigation of collision risks around the airport is having "eyes on" the UAS to maintain separation. This might involve a spotter on the ground, a chase plane in the air, or through positive radar control when the UAS transits to working areas. Should these methods not be practical, sterilization of the airspace becomes the default mitigation strategy. To better understand how SMS processes can be used toward successful UAS integration, the development of these aircraft collision risk mitigations is illustrated here.

UAS, SMS, and the Airport Operator

Fully developed SMS are coming to airports. Early adopters are finding that integrating SMS processes not only improves safety performance, but also adds value to the operational effectiveness of the airport. There are several Part 139 certificated and a handful of general aviation airports that have developed and implemented an SMS and much that can be learned from those airports. Appendix D provides links to SMS experienced airports and to the results from FAA sponsored SMS pilot studies involving several of them.

Developing and implementing an SMS that integrates UAS safety processes is a sound method of protecting the airport and gaining the confidence of the surrounding communities. A summary of SMS components and concepts, along with some examples of how they might be used to support UAS introduction is provided here.

SMS Components An SMS consists of four components; they are:

- Policy: The policy provides the safety direction, commitment to safety of airport management, and articulates the responsibilities for safety.
- Safety risk management (SRM): SRM provides the tools to identify hazards, assess their risks, and mitigate the risks. (This is the most important operational aspect of SMS, and therefore will be vital to addressing UAS operational risks.)
- Safety assurance: Safety assurance provides the data collection and analysis of safety processes, enabling management to understand how the system is performing.
- Safety promotion: Safety promotion provides the information and communication aspects of the overall safety program, along with safety training and orientation.

The introduction of UAS operations, in most cases, will represent a system change to an airport. This change to the system is not ordinary, and may require some distinctly different ways in which aircraft are operated. Therefore, some level of risk assessment is prudent on the airport operator's part. A system change is usually classified as a trigger to initiate a safety risk assessment (SRA), a process used in the SRM component of the SMS. As the introduction of UAS to the airport is considered and planned for, conducting an SRA to identify anticipated hazards and assess the associated risk will benefit the airport and the UAS operator. A great way to prepare for the submission of a COA application might be to conduct an SRA and submit the identified hazards and risk mitigations along with the application to demonstrate a proactive approach to UAS introduction.

The 5-Step Process The SRA employs a 5-step process for assessing the system change risks. The steps are:

1. Define the system: Identify the elements and stakeholders of the system within which the UAS will be operating.
2. Identify the hazards: Determine the hazardous conditions the UAS may be introducing into the airport system. Multiple hazards are possible.

3. Analyze the risks: Evaluate the possible outcomes of the hazardous conditions. Each hazard may have multiple effects associated with it.
4. Assess the risks: Risks are defined by two elements: severity (how bad the outcome might be) and likelihood (what is the possibility of the outcome occurring). The combination of the severity and likelihood provides the level of risk.
5. Mitigate the risks: Develop actions or strategies to reduce the risks identified to acceptable levels.

The FAA has used this fundamental approach in dealing with UAS introduction into the NAS. A simple example is:

1. The *system* is the NAS in its current state.
2. The *hazardous condition identified* is that UAS cannot currently meet the "see and avoid" requirement for aircraft operations.
3. The *potential outcome* of this hazard is that a UAS could collide with a manned aircraft, another UAS, terrain, and or facilities on the ground or in the air. An accident could result.
4. The risk has a *severity* of a catastrophic accident, and the *likelihood* of this occurring was determined to be high enough that the overall risk was deemed too high or unacceptable, and therefore needed to be mitigated.
5. One of the *mitigations* to reduce the risk is "eyes on" the UAS when the aircraft is moving. The use of a ground spotter or a chase plane was determined to provide the mitigation to reduce the likelihood of a collision, therefore reducing the overall risk to an acceptable level.

This explanation is oversimplified as months and years of effort and multitudes of data were used by the FAA to determine the appropriate mitigations. The FAA uses this process for each individual COA application in order to ensure each UAS operation is dealt with appropriately.

Airport operators are encouraged to learn and use this process to understand the risks associated with UAS operations at their airport. This process can and should be applied to all aspects of the UAS operation, not just when the UAS is moving on the ground or in the air.

8.2 Security and Access Control

The physical security and access control aspect of UAS will depend on the UAS operator's needs and the airport environment. Part 139 certificated airports have specific security and access control requirements because of the commercial aspect of the operation. For all airports looking to bring in UAS operations, modifications to the airport security and access control plan may be required. Airport operators can work with the UAS operator to define the specific, detailed UAS security requirements, and integrate them into the airport security and access plan using 49 CFR Part 1542, Airport Security, as guidance.

In the airport cases researched for the primer, the UAS operation fit into the existing security program at the particular airport. This was identified as one of the primary reasons the UAS operator began operations at the particular airports interviewed.

For many UAS systems, the personnel maintaining and operating the aircraft will need access to the majority of the airfield. Some UAS personnel may only need to access hangar and tie-down areas, while others will need full access to the movement and runway safety areas in order to launch and recover the aircraft. An airport might introduce a catapult launched system where the aircraft and support personnel transit to a remote part of the airport to conduct flight operations. Thorough planning will ensure the security of the operations and the airport in general.

Airport operators that anticipate UAS operations are forthcoming or are actively pursuing UAS tenants, may be well served by developing a security and access control plan that is tailored to meet a UAS operator's needs. The plan may include the following aspects:

- UAS isolation from other tenants and operations (perhaps using a completely separate facility)
- Controlled access to the facility (card access, lock and key)
- UAS operational security requirements (special considerations for when the UAS is moving on the ground or within close proximity to the airport, such as a total ground stop of other aircraft)
- Special UAS operator security requirements (data and document storage)
- Special UAS operator security requirements (data and communications transmission)

This list is intended to begin a thoughtful process on how security issues with UAS might be managed. In some cases, no additional security arrangements will be required, but sound planning and research will go a long way to ensuring a secure airport environment.

8.3 Emergency Response Requirements

UAS operations typically fit within the current emergency response plans and systems airports have in place. Outside of the thorough planning and implementation of lost link procedures and emergency holding points, no specific or unique emergency response requirements associated with UAS were introduced by the airports with UAS experience. In many cases, general aviation airports without dedicated emergency response assets merely made the responding authority aware of the UAS activity just as they would if a new tenant flying manned aircraft entered the operations and considerably increased the number of flights conducted from the airport.

Airport operators should consider an emergency response overview as part of any UAS education and outreach that they provide to their communities. Educating local law enforcement and fire departments should be a priority when UAS operations are anticipated or are in the planning stages. Emergency responders should be provided information such as UAS types, sizes, fuel types and capacities, propulsion systems, and payloads should the UAS suffer an accident. Providing this information and getting feedback from local responders may ensure the success of response actions and improving the public's perception of UAS.

8.4 Aircraft Rescue and Firefighting Considerations

ARFF considerations are driven by the type of UAS at the airport and the operational modes of the UAS. The ARFF personnel at some airports interviewed for the primer received specific UAS familiarization. As an example, the airport ARFF personnel at the VCV in Victorville, CA went through a complete familiarization of the different systems flown at the airport. The familiarization included briefings on the aircraft, the duties of the ground crews, and the general operation of the UAS on the ground and in the air. The familiarization was intended to make the ARFF personnel aware of any unique issues so that in the event of an emergency response, the ARFF personnel would have a sound understanding of the situations to which they could respond. The familiarization included but was not limited to the following:

- Fuel used and fuel tank placement
- Fuel shut off valve location
- Onboard fire suppression systems
- Control systems (onboard computers)
- Communication devices

- Payload access
- Operational characteristics (performance)

The ARFF considerations are listed on the checklist included in Appendix C for reference. For those airports that do not have ARFF coverage, the issue is still applicable and one to be discussed with the fire department that is responsible to the airport for response in the event of an emergency.

8.5 UAS Safety Incident Reporting

The success and acceptance by the public of expanded UAS operations will hinge partly on how safe and secure those in the communities served by airports feel with UAS flying above or near them. As UAS flight exposure increases, the likelihood of an accident or incident involving a UAS will also increase. Airport operators can play an important role in ensuring the successful integration of UAS into the NAS.

Airport operators will play an important role to ensure safe UAS operations. While the integration of runway dependent UAS at airports may take time, the introduction of small UAS is gaining momentum at a very rapid pace with many of the small UAS operators flying with a varied understanding of current rules and regulations. As discussed in Chapter 5, the draft rule for small UAS operations would prohibit flights within 5 miles of an airport unless the UAS operator has coordinated the activity with the airport and ATC. The airport operator can serve as a key enforcer and safety monitor for small UAS operations by knowing the rules, educating their communities on the rules, and reporting incidents to the FAA for both proper enforcement and safety data collection.

The FAA offers an Aviation Safety Hotline that can be used to report incidents involving UAS. The hotline can be reached by telephone by dialing 1-866-TELL-FAA (866-835-5322) and selecting Option 4. Incidents can also be reported by completing the form on the FAA Contact the Aviation Safety Hotline webpage located at https://www.faa.gov/contact/safety_hotline/.

Airports are also encouraged to use their individual safety reporting systems as a means to collect information on UAS safety. Such reporting systems are vital parts of an airport SMS. Whether the system involves a telephone hotline, a specific safety email address, or an anonymous means to report concerns, all airports including those that do not currently have UAS activity can plan important roles in ensuring the safe and successful growth of UAS operations in the United States.

CHAPTER 9

Moving Forward and Conclusions

If your airport is considering integrating unmanned aircraft into the airport's operations, what steps should the airport take to safely, securely, and efficiently integrate those operations? What preparations are necessary to get the process started and attract operators? With the commercial UAS industry still in the very early stages of development, this may be the best time for airports to begin planning and enter the UAS world prepared and ready to fly.

Three key areas addressed in the primer can help airport operators frame their plans.

1. **The operation of larger, runway dependent UAS at civil airports is manageable.** The airports and ATC with UAS experience have generally found that the operational differences introduced by larger UAS that require runways can be compatible with manned aircraft operations. The operational differences are aircraft type dependent. Given proper planning and well thought out procedures, UAS similar in size (wingspan and length) to manned, single engine light aircraft or larger can operate safely and efficiently in the airport environment. It will be important for airport operators to understand the characteristics of the UAS proposed for use at their facilities, and include all stakeholders, including members of the local community, in the planning stages.
2. **The communications infrastructure at the airport must support the needs of the UAS operator.** Many of the larger UAS that fly from airports are likely to have the pilot located at the airport. As these UAS move about the airport and fly in the landing pattern, continuous communications between the pilot or operator and the aircraft are necessary to safely fly the UAS. Additionally, many of the missions for the UAS that require the use of airport facilities are focused on gathering data and imagery. Not only will the aircraft require reliable communication with the pilot on the ground, the airport may also be called upon to be the receiver of large amounts of data transmitted from the aircraft. Having communications infrastructure in place or having the capacity to expand to the needs of the UAS operator will be important to successful UAS integration.
3. **Access to airspace UAS can use may attract UAS business.** At present, UAS operators need to have an approved COA in place before operations can begin. A challenge for airports is that the current COA process is aircraft dependent: a COA cannot be applied for or approved unless there is already a plan to operate from a certain location, to a certain location or area, using a specific aircraft and routing. Airports may be challenged in attracting UAS business without an approved COA in place. Airport managers can work with potential UAS operators to develop a COA and submit the plan for approval. This may seem like a dilemma for the airport. As the industry grows and matures, more UAS that require runways will grow and changes to how airspace authorization is granted will evolve. A proactive, cooperative approach by the airport together with UAS operators may lead to success.

Now that the FAA test sites are selected and testing and operations are beginning, information about the impact UAS have on airports will become more prevalent and available. Airport operators are encouraged to monitor industry progress by visiting the FAA website and its UAS pages and to use their local and state aviation associations for additional information about UAS. Other information resources are provided in Appendix A aimed at keeping the airport community up-to-date.

Preparing for UAS Checklist Airports looking to research and attract UAS activities may benefit from following the steps that other airports have taken. One such airport is the Chennault International Airport (CWF) in Lake Charles, LA. The steps the airport took to try to obtain UAS operations, and recommendations they have based on their efforts are listed below. The airport is still actively working to bring UAS businesses to their facilities.

1. **Engage with a UAS national test site.** The six national test sites provide airspace, approved COAs, and the resources of UAS partners to those looking to conduct UAS testing. Airports can contact the nearest test site to research options. Points of contact for the test sites are contained in Appendix A.
2. **Engage with area universities.** A number of universities around the country are doing research with UAS. Many are associated with a national UAS test site while others are conducting independent research. A partial list of universities with UAS programs is provided in Appendix A.
3. **Contact state government.** Informing the state economic development officials and Department of Transportation (Aviation Division) of the interest of the airport to integrate UAS operations may open up opportunities and resources.
4. **UAS conferences.** There are a number of conferences conducted annually where airport management can learn about the systems being developed and make contacts with UAS companies. Airport management can invite state officials and airport board members to join them in attending such conferences and present a united effort aimed at attracting UAS business.
5. **Investigate complementary UAS businesses.** The business models for the airport and supporting community may be set up in advance to support certain aspects of the UAS industry, such as airframe manufacturing, or avionics development.
6. **Determine UAS facility/infrastructure requirements.** Knowledge gained from conferences and industry research will likely steer the airport toward particular UAS related companies. Engaging with the companies will help determine their needs and anticipate any changes the airport may need to make.
7. **Contact the FAA.** Discussions with the FAA UAS Integration Office (AFS-80) regarding the steps taken by the airport to set the stage for UAS operations, and on the additional steps necessary to permit UAS operations from the airport will likely allow the airport to identify any remaining hurdles. The UAS Integration Office can provide answers on the current COA and airspace approval processes that may be the most challenging in the near term.

Establishing a COA in Advance of UAS Tenants A goal of airports like CWF is to draw UAS businesses to their facilities during the early stages of UAS industry growth and establish the airport as an attractive place to operate. The CWF airport manager and members of the airport staff have regularly attended UAS trade shows to meet potential tenants and discuss the advantages their airport has over others. In order for the companies to start business or relocate to Lake Charles, LA, a key factor is the availability of airspace in which to operate. The current COA application process is challenging for airports as it is designed for UAS operators applying to fly specific aircraft. Without an approved COA and without a commitment from a UAS operator to fly their aircraft from a new airport, the COA application process will be a hurdle for airports. The airport community may find it valuable to work with the FAA to address this challenge so that as more UAS that require airport runways and services are developed, airports will have a pathway to attract business.

This primer is not intended to be all inclusive and is written at a specific point of time in the growth of the UAS industry. Some of the information will be dated as soon as the primer is published, given the speed of change in the industry. The primer is intended to educate and provide information to airport operators that will spur a thoughtful approach to UAS integration and UAS operations. At the end of the day, communities look to their airport management as the aviation experts. Airport management will be asked for their opinions on UAS and asked specific questions about what the community should expect in regard to UAS operations. Airports that are informed and proactive will enable UAS industry development, garner community support, and ensure unmanned aircraft are successfully brought into the airports' way of doing business.

APPENDIX A

UAS References for Airports

A-1 FAA Test Site Descriptions and Contacts

A brief description of the six test site operators and the research they plan to conduct into future UAS use are here:

- *University of Alaska* The University of Alaska proposal contained a diverse set of test site range locations in seven climatic zones as well as geographic diversity with test site range locations in Hawaii and Oregon. The research plan includes the development of a set of standards for unmanned aircraft categories, state monitoring, and navigation. Alaska also plans to work on safety standards for UAS operations.
- *State of Nevada* Nevada's project objectives concentrate on UAS standards and operations as well as operator standards and certification requirements. The applicant's research will also include a concentrated look at how ATC procedures will evolve with the introduction of UAS into the civil environment and how these aircraft will be integrated with NextGen. Nevada's selection contributes to geographic and climatic diversity.
- *Griffiss International Airport (NY)* Griffiss International plans to work on developing test and evaluation as well as verification and validation processes under FAA safety oversight. The applicant also plans to focus its research on sense and avoid capabilities for UAS and its sites will aid in researching the complexities of integrating UAS into the congested, northeast airspace.
- *North Dakota Department of Commerce* North Dakota plans to develop UAS airworthiness essential data and validate high reliability link technology. This applicant will also conduct human factors research. North Dakota's application was the only one to offer a test range in the temperate (continental) climate zone and included a variety of different airspace that will benefit multiple users.
- *Texas A&M University—Corpus Christi* Texas A&M plans to develop system safety requirements for UAS vehicles and operations with a goal of protocols and procedures for airworthiness testing. The selection of Texas A&M contributes to geographic and climactic diversity.
- *Virginia Polytechnic Institute and State University (Virginia Tech)* Virginia Tech plans to conduct UAS failure mode testing and identify and evaluate operational and technical risks areas. This proposal includes test site range locations in both Virginia and New Jersey.

Table A-1 provides contact information.

Table A-1. UAS test site points of contact.

Awardee		Point of Contact	
State	**Awardee Name**	**Role**	**Address**
Alaska	University of Alaska	Pan-Pacific UAS Test Range Complex Director and Deputy Director, ACUASI	903 Koyukuk Drive PO Box 757320 Fairbanks, AK 99775 North Star County
North Dakota	North Dakota Department of Commerce	Director, Economic Development and Finance Division	1600 East Century Avenue, Suite 2 Bismarck, ND 58503 Burleigh County
Nevada	State of Nevada	Communication Director	Governor's Office of Economic Development Grant Sawyer Bldg. 555 East Washington, Suite 5400 Las Vegas, NV 89101
New York	Griffiss International Airport	NUAIR Technical Director	592 Hangar Rd., Suite 200 Rome, NY 13441 Oneida County
Texas	Texas A&M University-Corpus Christi	Senior Research Development Officer	6300 Ocean Drive Corpus Christi, TX 78412 Nueces County
Virginia	Virginia Polytechnic Institute and State University (Virginia Tech)	Director	ICTAS Building Stanger St. (0193) Blacksburg, VA 24061 Montgomery County

A-2 FAA UAS Information

The following websites steer the user toward key pages on the FAA website related to UAS.

- FAA home page for Unmanned Aircraft Systems: https://www.faa.gov/uas/
- FAA UAS fact sheet: https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=14153
- FAA COA webpage: http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/systemops/aaim/organizations/uas/coa/
- Examples of approved COAs: http://www.faa.gov/uas/public_operations/foia_responses/
- Details on gaining approval for non-governmental UAS operations: http://www.faa.gov/uas/civil_operations/
- Section 333 of the *FAA Modernization and Reform Act of 2012*: https://www.faa.gov/uas/media/Sec_331_336_UAS.pdf
- Small UAS Rulemaking Announcement (Press Release): http://www.faa.gov/news/press_releases/news_story.cfm?newsId=18295
- Overview of Small UAS Notice of Proposed Rulemaking: http://www.faa.gov/regulations_policies/rulemaking/media/021515_suas_summary.pdf
- FAA Flight Standards Information System—Volume 16: Unmanned Aircraft Systems: http://fsims.faa.gov/PICResults.aspx?mode=EBookContents&restricttocategory=all~menu
- FAA Advisory Circular 91-57 on Model Aircraft Operating Standards: https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentid/22425

A-3 FAA Links for Grant Assurance

AIP provides grants to public agencies—and, in some cases, to private owners and entities—for the planning and development of public-use airports included in the NPIAS. The following resources may assist airports in applying for grants in support of UAS integration:

- National Plan of Integrated Airport Systems (NPIAS): http://www.faa.gov/airports/planning_capacity/npias/
- Overview: What is AIP & What Airports/Projects are Eligible? (http://www.faa.gov/airports/aip/overview/)
- Acquiring Land for Airports and Relocation Assistance: (http://www.faa.gov/airports/environmental/relocation_assistance/)
- AIP Grant Payments—Delphi eInvoicing: (http://www.faa.gov/airports/aip/grant_payments/)
- Benefit-Cost Analysis: (http://www.faa.gov/airports/aip/bc_analysis/)
- Grant Assurances for the AIP: (http://www.faa.gov/airports/aip/grant_assurances/)
- Letter of Intent (LOI) Program: (http://www.faa.gov/airports/aip/loi/)
- Military Airport Program (MAP): (http://www.faa.gov/airports/aip/military_airport_program/)
- Procurement and Contracting Under AIP: (http://www.faa.gov/airports/aip/procurement/)
  - Buy American Preferences: (http://www.faa.gov/airports/aip/buy_american/)
  - Nationwide Buy American Waivers Issued (PDF): (http://www.faa.gov/airports/aip/buy_american/media/nationwide-buy-american-waivers-issued.pdf)
- State Block Grant Program: (http://www.faa.gov/airports/aip/state_block/)

A-4 FAA Link for Airworthiness Information

The following websites provide additional information regarding Air Worthiness Requirements for aircraft in the United States:

- FAA Order 8130.2G—Change 1 Incorporated: http://www.faa.gov/documentLibrary/media/Order/8130.2G%20.pdf
- FAA Order 8130.2G Change 1 Only: http://www.faa.gov/documentLibrary/media/Order/Chg%201%20%208130.2G%20.pdf

A-5 University UAS Resources

The following is a listing of some of the universities that offer UAS related programs, courses, and research:

- Embry-Riddle Aeronautical University: http://daytonabeach.erau.edu/degrees/bachelor/unmanned-aircraft-systems-science/
- Indiana State University: http://technology.indstate.edu/uas/
- Kansas State University—Salina: http://www.salina.k-state.edu/aviation/uas/
- Oklahoma State University: https://unmanned.okstate.edu/
- Purdue University: https://tech.purdue.edu/degrees/unmanned-aerial-systems
- Texas A&M University of Corpus Christi: http://lsuasc.tamucc.edu/
- University of Cincinnati: http://ceas.uc.edu/news-1415/uavtops.html
- University of Minnesota: http://www.uav.aem.umn.edu/
- University of Nevada Reno: http://www.unr.edu/degrees/uas/
- University of North Dakota: http://www.uasresearch.com/home.aspx
- Unmanned Vehicle University: http://www.uxvuniversity.com/
- Virginia Polytechnic Institute and State University: http://www.unmanned.vt.edu/

A-6 Additional UAS Resources

The following resources provide additional information that may benefit the airport operator in gaining knowledge on UAS systems:

- Association of Unmanned Vehicles International: http://www.auvsi.org/about
- ASSURE (Alliance for System Safety of UAS through Research Excellence)—The FAA's UAS Center of Excellence for UAS Research: http://www.assureuas.org/
- *ACRP Report 76: Addressing Uncertainty about Future Airport Activity Levels in Airport Decision Making*: http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_076.pdf
- "Know Before You Fly" Website: http://knowbeforeyoufly.org/

APPENDIX B

Modes of UAS Operations

To begin understanding UAS and how airports best position to support their operations, a good starting point is the modes of UAS operations and aspects of the operations airport managers should consider during planning. The following modes of UAS operations descriptions are derived from interviews with UAS operators and airport personnel with UAS experience, the operational experience of the research team gained primarily with military UAS units, and from the FAA document: *Interim Operational Approval Guidance 08-01 Unmanned Aircraft System Operations in the U.S. National Airspace System.*

This appendix includes description of several systems used to classify different UAS along with some representative examples. It also covers critical modes or phases of UAS operations with which the airport operator may want to be familiar in order to better ensure smooth introduction and operations. These phases include:

- Airfield/site survey and electromagnetic analysis
- System deployment and preparation
- Ground operations
- Taxi operations
- Takeoff
- Climb out
- Navigation to operational areas
- Area of operation
- Return to base/descent
- Landing
- Parking and shutdown

B-1 Classifying UAS

An ever growing variety of unmanned systems provide an increasing number of applications for civilian and military organizations. The UAS come in numerous configurations, sizes, and characteristics. Because of the wide assortment of systems, it is helpful to differentiate between them by breaking them into groups or categories.

There are a number of different ways to categorize UAS. The U.S. military uses a tiered classification system based primarily on the mission of the UAS. At the time of primer development, the FAA was focused on rulemaking for two classes of UAS based on weight: small UAS weighing no more than 55 pounds or 25 kilograms and micro-UAS weighing no more than 4.4 pounds or 2 kilograms.

In a course entitled *Geospatial Applications of Unmanned Aerial Systems (UAS)* offered by Penn State University, a course unit on "Classification of the Unmanned Aerial Systems" states that there is

> . . . no one standard when it comes to the classification of UAS. . . . Defense agencies have their own standard, and civilians have their ever-evolving loose categories for UAS. People classify them by size, range and endurance, and use a tier system that is employed by the military.

The Penn State University course suggests that for classifying UAS according to size, the following system of sub-classes is sometimes used:

- Very small UAVs—up to 30 to 50 cm long, such as the Australian Cyber Technology CyberQuad Mini. This class includes the sub-classes Micro or Nano UAVs, and Mini UAVs.
- Small UAVs—between 50 cm and 2 meters in one dimension, such as the RQ-11 Raven.
- Medium UAVs—UAS with a wingspan of 5 to 10 meters and can carry payloads of 100 to 200 kg, such as the RQ-5A Hunter.
- Large UAVs—large UAS used mainly for military roles, such as the MQ-1 Predator.

Range and Altitude UAS also can be categorized in terms of their range and altitude limits. Here are some categories the DOD uses:

- Hand-held 2,000 ft. (600 m) altitude, about 2 km range
- Close 5,000 ft. (1,500 m) altitude, up to 10 km range
- NATO type 10,000 ft. (3,000 m) altitude, up to 50 km range
- Tactical 18,000 ft. (5,500 m) altitude, about 160 km range
- MALE (medium altitude, long endurance) up to 30,000 ft. (9,000 m) and range over 200 km
- HALE (high altitude, long endurance) over 30,000 ft. (9,100 m) and indefinite range
- HYPERSONIC high-speed, supersonic (Mach 1–5) or hypersonic (Mach 5+) 50,000 ft (15,200 m) or suborbital altitude, range over 200 km
- ORBITAL low earth orbit (Mach 25+)
- CIS Lunar Earth-Moon transfer
- Computer Assisted Carrier Guidance System (CACGS) for UAS

Size and Performance Another means of classifying UAS is by the size or weight of the aircraft, together with the airspeed and altitude regimes in which they fly. The DOD uses a group classification system such described in the *Joint Concept of Operations for Unmanned Aircraft Systems.* The groups are summarized in Table B-1. The table also includes some representative systems that fall into each group. Within this group system, if an aircraft has one characteristic that falls into a higher group, the aircraft is classified within that higher group.

The DOD group system is the reference for the remainder of the discussion in Appendix B.

B-2 Examples of UAS Airports May See

The following are images along with some specifications of some of the UAS that an airport operator might see flying near or from an airport. While not every model is runway dependent, an airport could provide facilities for each type of aircraft. For example, the Southern California Logistics Airport has California National Guard Units flying the Raven on the airport property during training exercises. The aircraft are identified by the groups shown in here.

Table B-1. UAS classifications.

UAS Groups Classifications	
GROUP	**UAS NAME (Model Type Examples)**
Group 1 • 0-20 lbs. • < 100 knots • < 1,200 ft. above ground level	• Raven • WASP • Puma • T-Hawk
Group 2 • 21-55 lbs. • < 250 knots • < 3,500 ft. above ground level	• Scan Eagle • Silver Fox • Aerosonde
Group 3 • < 1,320 lbs. • < 250 knots • < 18,000 ft.	• Hunter • Shadow • Blackjack • Tiger Shark • Mako II
Group 4 • > 1,320 lbs. • Any airspeed • < 18,000 ft.	• Hummingbird • Fire Scout • Predator • Grey Eagle
Group 5 • > 1,320 lbs. • Any airspeed • > 18,000 ft.	• Reaper • Global Hawk

Group 1

U.S. Army Photo

Raven - RQ-11	
Wingspan	4.5 ft.
Maximum Takeoff Weight	4.2 lbs.
Launch and Recovery	Hand-launch/auto land

Group 2

U.S. Navy/John F. Williams

Insitu ScanEagle	
Wingspan	10.2 ft.
Maximum Takeoff Weight	48.5 lbs.
Launch and Recovery	Catapult launch/rope and hook recovery

Group 3

Northrop Grumman Corp.

Hunter - RQ-5	
Wingspan	29.2 ft
Maximum Takeoff Weight	1,974 lbs.
Launch and Recovery	Automated rolling takeoff and landing

Group 4

U.S. Air Force photo/Staff Sgt. Brian Ferguson

Predator - MQ-1B	
Wingspan	55 ft.
Maximum Takeoff Weight	2,250 lbs.
Launch and Recovery	Pilot controlled runway takeoff and landing

Group 5

Photo courtesy Ben Trapnell, Northrop Grumman

Global Hawk - RQ-4	
Wingspan	130.9 ft.
Maximum Takeoff Weight	32,250 lbs.
Launch and Recovery	Pilot controlled runway takeoff and landing

B-3 UAS Critical Modes or Phases

The steps necessary to prepare for UAS operations and then conduct the flights are described in this section of Appendix B. These modes and phases are primarily derived from the experiences of organizations flying UAS in support of military operations and training. The information may differ from that of some civilian UAS organizations flying UAS from airports, but is representative of what airport operators can expect as they introduce UAS into daily operations.

Site Survey/Airfield and EMS Analysis

In order for UAS operations to be successful at an airport, communications and data transfer methods are a top priority. The guarantee of excellent communication links between the

GCS (ground control station) and the UAS is an important facet for the successful installation, integration, and operation of UAS at an airport. Before beginning UAS operations or when exploring the airport infrastructure needs for UAS integration, a site survey must be done to include an electromagnetic and frequency analysis. The survey should also include a study of optimal locations for GCS and the associated data-link antennas prior to any UAS flight operations. For public safety, this survey helps ensure, to the extent possible, the highest quality communications link between the GCS and the UAS across the entire airport environment. This study should consider not only the designated ramps, taxi routes, airport structures, and takeoff/landing corridors, but all natural environmental surroundings and obstructions.

System Introduction and Deployment

Setting Up the System Following completion of the site survey to confirm the airport meets UAS requirements, the systems can be deployed. Once deployment is approved, the ground equipment and its supporting components [such as GCS, ground data terminals (GDT), and hangars or shelters] are constructed, assembled, or positioned in the predetermined locations. This may require the use of large equipment and trucks, especially for systems that require the use of catapult launch and net systems for UAS recovery. The amount of ground equipment and support components needed is entirely dependent upon the size and complexity of the UAS being deployed.

Fiber Optics For larger systems used for imagery, reconnaissance, or video monitoring, large amounts of data may be transmitted from the aircraft to the operators at the airport. Fiber optic cables connect the GCS to the ground data terminal. The length of the cables is usually limited by the system manufacturer to ensure there is no degradation of signal. These cables need to be protected and may require that they be buried underground.

Airport Orientation Early in the UAS deployment, all stakeholders in the operation of the UAS will benefit from orientation meetings. Airport staff, UAS operations personnel, ATC, and airport tenants who may be impacted as UAS flights begin can be invited to a meet and greet. The topics addressed during orientation meetings might include:

- UAS system specifics and limitations
- Local ATC procedures and course rules
- Airport facilities
- Airport tenant schedules and points of contact
- Emergency procedures unique to the UAS
- Safety practices and reporting procedures

The meetings should be designed not only to orientate the UAS pilots and staff with the airport policy and procedures, but to familiarize and acquaint the various airport departments, tenants, and their personnel to the UAS components and operational requirements. Orientation meetings can go a long way toward instilling confidence and cooperation between UAS stakeholders at the airport.

Examples of two by-products that result from these working meetings are the development and approval of the following:

- Depiction of all UAS operation areas on FAA Sectional charts as intense UAS activity
- Issuing NOTAMs with detailed information regarding individual UAS operational areas. (An example of wording that can be used for a NOTAM issued for UAS operations can be found in Appendix C-1.)

Community Support Garnering community acceptance and support for UAS operations is discussed in Chapter 4 of the primer. The UAS community and airport operators will likely need to take additional steps to address public apprehension from members of the general aviation community and from local businesses. By participating in local aviation safety organization meetings and programs offered by the Aircraft Owners and Pilots Association (AOPA), Experimental Aircraft Association (EAA), and FAA safety meetings, the UAS and airport operators can address questions, concerns, perceptions, and misconceptions.

A larger challenge for airport operators may be addressing the concerns of persons and organizations who are not participants or beneficiaries of the operations of unmanned aircraft. By engaging with local business associations, such as the chamber of commerce, the airport and UAS operators may discuss business associated with UAS that can benefit the overall economy of the community.

Ground Operations

Ramp Area UAS ground operations are an important element for airports to take into consideration. The ground equipment used for UAS is often different than that needed for manned aircraft and may need to be in place for specific amounts of time prior to taxi or takeoff. Typical ground operations involving a UAS include:

- Pre-positioning of the aircraft
- Pre-positioning of GSE
- Fueling operations
- Maintenance and aircrew preflight of the aircraft and all required GSE
- GCS setup, configuration, and preset (as required)
- Aircraft initial link
- Link checks
- Engine start and run-up (as required)
- Taxi

Managing Frequencies As a precaution, a frequency manager may be used to help assign, monitor, and deconflict data-link frequencies during all UAS operations. With numerous and possibly various types of UAS operating within the designated ramp area or operations area, it is essential that each UAS utilizes an assigned frequency in order to prevent stepping on and/or forcing other participating systems into lost link situations.

For example, two UAS, regardless of their system, could be assigned different frequencies for the entire day or for a period of time. If one UAS is currently operating on its assigned data-link frequency while taxiing and the second UAS accidentally powers up on the incorrect frequency, there are two possible outcomes: the air vehicle taxiing will be forced into lost link or the GCS powering up will not be able to establish link with the aircraft.

If a UAS experiences a lost link condition while the engine is running, the computer logic commands the engine to shut down and apply brakes. Similar to manned aircraft, this is not considered an emergency situation, but ATC will be notified of the short delay in order to allow UAS ground maintenance to assist with removal of the aircraft from the ramp or the movement area.

Taxi Operations

Similar to Manned Aircraft One of the challenges during taxi operations for the UAS pilot is maintaining airport situational awareness while taxiing to and from active runways.

Identical to manned pilots, the UAS pilot must be able to navigate by identifying runway and taxi information markings (such as centerlines, edge lines, hold short lines, airfield lighting), as well as avoid unintentional runway incursions.

Using GPS Although GPS is very robust by itself, some UAS provide additional equipment to assist the pilot. The equipment might include a nose camera displaying a certain field of view (FOV) to the GCS, geo-rectified airport taxi maps, GPS overlays reporting real-time air vehicle position on selected maps, and ground chase. Experience with U.S. military unmanned aircraft has shown that UAS using GPS to taxi benefit from the use of fixed taxi routes to avoid ground traffic conflicts.

Controlled Taxi Additionally, at controlled airports, ATC monitor all aircraft regardless of being manned or unmanned. It is extremely helpful for aircrews to employ ATC guidance for unforeseen conditions such as blind turns, unlit taxiways, faded runway markings and signs. Their assistance to provide direct routes and adequate separation between aircraft increases the quality of data links and also helps minimize inclement weather effects on the UAS. This helps ensure overall airport flow efficiency.

Uncontrolled Airfields At non-towered airports, coordination with the airport owner and operator might be necessary to ensure the taxi route to the active runway is clear and the most direct route is available. Even more importantly, communications with other airport users via Unicom or Multicom radio(s) and UAS intentions and movements is critical to general airport safety.

Takeoff

Using Runways For runway dependent UAS, normal takeoff procedures are typically the same as manned aircraft. Takeoff pre-planning is important, regardless of runway dependency. Prior coordination of expected takeoff instructions such as traffic pattern, traffic pattern altitude (if nonstandard), assigned emergency mission zones, and departure procedures can help to avoid prolonged takeoff delays and to allow the operator to program the system accordingly.

Not Using Runways For runway independent UAS, such as those using a catapult launching system, the takeoff typically requires a designated location, which may not limited to the immediate airport environment. However, there are many vertical takeoff and landing (VTOL) UAS in the small categories that are hand-launched or depart from the ground and do not require a mechanical assist for takeoff. A typical UAS launch site has minimal requirements other than a clear launch/climb out corridor and support vehicle access route to relocate and load a fully pre-assembled and operational UAS from the maintenance site to the launch site.

Unique Takeoff Modes Because the catapult, hand-launch, and direct takeoff launching systems do not require any improved surfaces, UAS operations within the immediate airport environment are not limited to prepared surface areas. A catapult can be set up utilizing grass areas between the runways and taxiways or in areas away from the runways. This may help to decongest runways and taxiways.

Climbout

Much like manned aircraft, a typical UAS climbout keeps the aircraft within the traffic pattern or very close to the airport environment until sufficient altitude is achieved prior to proceeding on the assigned route. The primary reason for staying within the traffic pattern is to maintain the best aircraft positioning possible in case of an emergency; the UAS is in a more desirable position to recover safely.

Navigation to Operational Areas

The directive and procedure approval process for UAS navigation to and from operational areas is managed by the FAA. The routes are designated in the COA. A COA does not require a restricted type certification, or vice versa. COAs require FAA approval on a case-by-case basis. The items below are some of the topics that need to be assessed during the COA approval process:

- Operation area(s) with altitude restriction(s)
- Transition routes and procedures
- Navigation and strobes requirements
- TCAS, ADS, and transponder requirements
- Active/passive communication requirements
- Lost link route(s) and procedures

Areas of Operation

Due to the multitude of types of operations, missions, or tasks for which a UAS can be used, the procedures put in place are strongly dependent on the UAS mission itself. Some of these tasks and missions support public agencies, and some are commercial in nature. As a reference, typical UAS missions might include the following:

- Illegal trafficking monitoring
- Counter drug operations
- Traffic/accident control
- Police support
- Border control monitoring and support
- Fire department overhead support
- Search and rescue
- Natural disaster support
- Emergency management
- Real estate property survey and photogrammetry
- Power line/oil pipe inspection
- Film industry support
- Wildlife management
- Surveillance of commercial high-value assets
- Precision agriculture
- Agriculture field monitoring
- Delivery services (potential future use)

The varieties of areas where a UAS can be used make it difficult to identify the operational requirements in every field of employment. If the system is used in conjunction with police, border protection, law enforcement, firefighting, or any other federal and state agency, priority integration into the NAS for such flights might be needed to enhance mission efficiency, effectiveness, and safety. From an airport ATC point of view, strong coordination will be required to include the UAS into normal civil aircraft management as authorization for airspace use is typically granted real time on a first come, first served basis. Introduction of the UAS into normal airport operations will require ATC to coordinate aircraft operations and avoid conflicts.

For non-airport launched commercial UAS operations, the coordination required with airport operations is more difficult to assess. This assessment depends on where the UAS areas of operations occur and at what altitude the UAS operate. If near to the departing airport, a strong effort is needed by ATC to keep track of the UAS position, and provide traffic advisory and deconfliction between general aviation traffic and the UAS.

Return to Base

Generally speaking, the same procedures and considerations applied during climb out and navigation to operational area are applied to the UAS return to base (RTB) routing, descent, and arrival procedures. An additional element for consideration is an abnormal or unanticipated reason for the UAS to return, such as an inflight emergency or unpredicted developing weather.

Not all unmanned systems have the ability or resources available to divert to alternate airports, like manned aircraft. Even though UAS pilots typically plan to RTB at least one hour prior to any undesirable weather conditions, the UAS may request priority handling (when possible) in order to mitigate risk when encountering unexpected conditions or elements.

Landing

Similar to takeoffs, different UAS have different landing modes. In general, larger runway dependent UAS have two types of landing modes. They are a manual/camera aided landing where the pilot has a cockpit view to aid in the landing process and an auto-landing mode where the aircraft follows a predetermined course and descent profile without input from the pilot or UAS operator.

Using Runways There are several types of runway dependent UAS that require additional support equipment to land. This support equipment could include things such as a UAS specific arresting cable to assist with stopping or a diode placed on the runway for UAS that have an auto landing capability. Additional analysis to determine the effect of options such as these on existing operations at an airport will be needed. Landing issues yet to be fully resolved include if an arresting cable could be left in place without causing interference to existing traffic, or if the diode could be permanently placed in an area where it could be in close proximity to the UAS requiring its use without affecting existing traffic.

Not Using Runways Runway independent UAS can take advantage of the other areas of the airport and its surround environment for landings. While some systems require an extremely short area of a semi improved surface, others may only require a place to set up a medium to large size recovery net. The size of the unimproved and undesirable areas of an airport will be based on the required UAS landing footprint.

Pattern Considerations Although not a requirement, preliminary steps can be taken to increase safety with UAS in the airport traffic pattern. One approach is to have the UAS traffic patterns opposite of manned airplane patterns (e.g., right traffic patterns for UAS as opposed to a left traffic patterns for manned aircraft) to avoid any kind of conflict during a critical phase of flight. UAS operators may be limited in their FOV and thus more reliant on ATC instructions and deconfliction services. It is typical for UAS to slightly extend pattern legs, require nonstandard pattern altitudes, or to require additional time to clear the active runway.

The Challenge of Landing For many UAS, like the MQ-1 Predator, landing is the most challenging phase of flight. This fact makes it common for the aircraft to make multiple attempts at landing. In cases where these aircraft need to land at a commercial airport, ATC needs to be prepared for a go around, and be able to properly provide aircraft separation in the surrounding airspace. Controllers might also need to allow more "in-trail" separation with commercial aircraft as the larger UAS aircraft need a long straight-in approach to alleviate some of these issues.

Parking/Shutdown

Due to the limited airfield situational awareness and depth perception of the UAS aircrews, a maintenance crewmember typically marshals the UAS into the assigned parking spot, identical to any commercial operation. In addition to standard hand signals, maintenance crews also employ voice communications with the aircrew to ensure safety and clear lines of communication at all times.

Additional Operational Considerations

Public Versus Civil UAS At present, the vast majority of UAS operations conducted at airports are under the authority of the U.S. military or other government agencies, and are considered public UAS operations. The operation of civil UAS, especially small UAS, at civil airports may be different from these operations in some ways. Until those operations begin, it is not possible to project the limitations, requirements, or approvals that may be required by the FAA.

Larger Airports in the Future? As technical means grow to address key safety issues, such as airborne detect-and-avoid systems, civil data links, and privacy and security issues, operations may expand into more populated areas and to larger airports where more sophisticated operations will be involved. In these cases, the UAS will be required to operate much like manned aircraft. The airport considerations to support more advanced UAS operations will deal mainly with providing the unique infrastructure that is needed to enable such routine operations by UAS, and the safety systems necessary to ensure safe operations.

Every UAS system has its own nuances and requirements that need to be analyzed separately by looking at things such as vehicle description, vehicle performance, operator qualifications, operating procedures, and emergency profiles and procedures. Most of these are addressed during UAS certification and may or may not be of concern to the airport operator. Proper planning and analysis are keys to the successful integration of UAS into the airport environment.

APPENDIX C

UAS Checklists and Unique Procedures

C-1 Sample NOTAM

The following are examples of NOTAM posted for two airfields with regular UAS activity. Both airports have civilian air traffic with Killeen-Fort Hood Regional Airport having daily commercial air carrier service.

Robert Gray Aaf (*Killeen-Fort Hood Regional Airport*)

NOTAM #: L0187/15

Facility: GRK

Class: Military

Start Date: 13 Apr 2015 1400 UTC

End Date: 16 Apr 2015 2200 UTC

Status: Active

L0187/15 NOTAMN

Q) /QXXXX

A) KGRK KHLR

B) 201504131400

C) 201504162200

E) UAS OPERATIONS WITHIN THE ROBERT GRAY AAF CLASS D AIRSPACE, SURFACE TO 3500' MSL, AND WITHIN R-6302A, C, AND D, 5,500' MSL TO 10,500' MSL, CLASS 4 NON-EYE SAFE LASER OPS WITHIN THE RESTRICTED AREA, 1400Z (0900L) TO 2200Z (1700L) DAILY, 13 TO 16 APR 15.

Southern California Logistics

NOTAM #: 04/012

Facility: VCV

Class: Airspace

Start Date: 14 Apr 2015 1430 UTC

End Date: 17 Apr 2015 2359 UTC

Status: Active

!VCV 04/012 VCV AIRSPACE UNMANNED ACFT WITHIN AN AREA DEFINED AS 5NM RADIUS OF VCV SFC-5400FT DLY 1430-2359 1504141430-1504172359

C-2 Facility and Operations Requirement Checklist

The following checklist lists key considerations for an airport introducing UAS operations. The checklist may change or need to be edited as each unmanned system is unique and has individual requirements.

Topic	Need	Description
Communication requirements		
Data storage requirements		
UAS storage needs (hangar)		
UAS ramp space		
Ground based control station		
UAS performance (takeoff and landing or launch and recovery method(s), and speed)		
UAS performance specific to runway and taxiway (ADG of UAS)		
Fuel type and storage		
Maintenance requirements		
Support services		
Material storage		
Any special payload handling required		
Any special environmental impact concerns		
Land-use considerations (zoning, encumbrances, etc.)		
Security requirements		
ARFF and emergency response		
Other		

APPENDIX D

UAS Airport Safety Information

D-1 SMS Resources

The safety of UAS operations at an airport will be a team effort between the UAS operator, ATC, and airport management and staff. From the airport perspective, a good starting point might be to ensure that UAS safety is included in the airport SMS, and that a SRA is conducted prior to the beginning of operations.

The information and resources available relating to the concepts and processes for safety management in aviation is growing. This appendix includes some of the key resources available and applicable to airports.

SMS Guidance, Tools, and Related Information

- FAA Advisory Circular 150/5200-37, Introduction to Safety Management Systems for Airport Operators: (http://www.faa.gov/airports/resources/advisory_circulars/index.cfm/go/document.current/documentNumber/150_5200-37)
- FAA Order 5200.11, FAA Airports (ARP) Safety Management System: (http://www.faa.gov/regulations_policies/orders_notices/index.cfm/go/document.information/documentID/323070)
- FAA Safety Management Systems Website: (http://www.faa.gov/about/initiatives/sms/)
- ICAO Safety Management Manual (Version 3): (http://www.icao.int/safety/SafetyManagement/Documents/Doc.9859.3rd%20Edition.alltext.en.pdf)
- Transportation Research Board (TRB) Airport Cooperative Research Program (ACRP) (http://www.trb.org/ACRP/Public/ACRP.aspx)
  - *ACRP Report 1: Safety Management Systems for Airports, Volume 1: Overview* (http://www.trb.org/Publications/Blurbs/159030.aspx)
  - *ACRP Report 1: Safety Management Systems for Airports, Volume 2: Guidebook* (http://www.trb.org/Publications/Blurbs/162491.aspx)
  - *ACRP Synthesis 37: Lessons Learned from Airport Safety Management Systems Pilot Studies* (http://www.trb.org/Main/Blurbs/167600.aspx)
  - *ACRP Legal Research Digest 19: Legal Issues Related to Developing Safety Management Systems and Safety Risk Management at U.S. Airports* (http://www.trb.org/Publications/Blurbs/168405.aspx)

Additional Resources

- AC 120-92A, Safety Management Systems for Aviation Service Providers: (http://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/319228)

- ARP 4754, Certification Considerations for Highly Integrated or Complex Aircraft Systems (see Appendix A): (http://standards.sae.org/arp4754/)
- ARP 4761, Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment: (http://standards.sae.org/arp4761/)
- FAA Order 8000.369A, Safety Management System Guidance (http://www.faa.gov/regulations_policies/orders_notices/index.cfm/go/document.current/documentNumber/8000.369)
- FAA System Safety Handbook: (http://www.faa.gov/regulations_policies/handbooks_manuals/aviation/risk_management/ss_handbook/)
- FAA Order 8040.4A, Safety Risk Management: (http://www.faa.gov/regulations_policies/orders_notices/index.cfm/go/document.current/documentNumber/8040.4)

APPENDIX E

Acronyms and Glossary of Key Terms

This appendix contains a list of acronyms and a glossary of key terms used in the UAS industry. Most of the acronyms and key terms were taken from the FAA or the U.S. military. When an acronym or term was taken from another source it is noted accordingly. The lists include some acronyms and terms not used in the primer but may be of interest to the airport operator introducing UAS operations to the airport. The intent is to be as inclusive as reasonably possible.

E-1 Acronyms

AC—advisory circular

ADS–B—automatic dependent surveillance–broadcast. The FAA air traffic organization describes ADS-B as follows:

- Automatic
  - Periodically transmits information with no pilot or operator input required
- Dependent
  - Position and velocity vector are derived from the global positioning system (GPS) or a flight management system (FMS)
- Surveillance
  - A method of determining position of aircraft, vehicles, or other assets
- Broadcast
  - Transmitted information available to anyone with the appropriate receiving equipment

ARC—Aviation Rulemaking Committee

ASTM—American Society of Testing and Materials (formerly)

AUVSI—Association of Unmanned Vehicle Systems International: The world's largest nonprofit organization devoted exclusively to advancing the unmanned systems and robotics community. Serving more than 7,500 members from government organizations, industry, and academia, AUVSI is committed to fostering, developing, and promoting unmanned systems and robotic technologies. AUVSI members support defense, civil, and commercial sectors.

AV—air vehicle: Synonymous with UAS.

AVO—air vehicle operator: Synonymous with pilot-in-command (PIC).

BLOS—beyond line-of-sight: A term often used by the military to describe radio communications capabilities that link personnel or systems which are too distant or too fully obscured by terrain for line-of-sight (LOS) communications. Some UAS are able to travel outside of LOS and use a satellite link to transmit and receive signals to or from the GCS. The civilian industry also uses the terms **BVLOS**—Beyond Visual LOS and **BRLOS**—Beyond Radio LOS.

BW—bandwidth: The width of the range (or band) of frequencies that an electronic signal uses on a given transmission. BW with regard to computers is the rate of data transfer, or bit rate throughput. This is what controls the amount of data that can be uplinked and downlinked to or from a UAS.

CASA—Civil Aviation Safety Authority

CFR—Code of Federal Regulations

CL—command link: When controlling the UAS in Ku-band, the CL is the package of information sent to the aircraft from the GCS to control it. The CL can also be sent in other parts of the electromagnetic spectrum.

CNS—communication, navigation, and surveillance

COA—Certificate of Waiver or Authorization: Authorization to operate a UAS for non-recreational purposes in the United States. COAs are limited to public UAS operations. The FAA approves and authorizes a COA.

CPA—conventionally piloted aircraft

CR—close range: Category of UAS able to fly up to 10,000 feet for 2 to 4 hours with an operating range of 5 to 10 miles (military exclusive term).

DAA—detect-and-avoid: Term used instead of sense and avoid in the Terms of Reference for the Radio Technical Commission for Aeronautics (RTCA) Special Committee 228. This new term has not been defined by RTCA and may be considered to have the same definition as sense and avoid when used.

DAL—design assurance level

DLTV/DTV—daylight television sensor which can be installed on a UAS and operates in the visible region of the electromagnetic spectrum.

DOD—U.S. Department of Defense

EASA—European Aviation Safety Agency

ECU—Environmental Control Unit: Used to control and regulate the inside of the GCA to protect sensitive electronic equipment and allow a comfortable environment for the crew.

EO/IR—electro optical/infrared: Sensor which operates in the visible and/or infrared regions of the electromagnetic spectrum.

EP—external pilot: Refers to a pilot who controls an aircraft but is not actually on board. A UAS pilot controls the aircraft from a GCS and is referred to as an external pilot. GCS as used here includes hand-held transmitters used by an external pilot using VLOS procedures.

FAA—Federal Aviation Administration

FGCS—fixed ground control station: A military term synonymous with GCS which refers to the UAS control center, housed in a customer-furnished building, used to control one or more UASs. The FGCS is designed primarily for mission control element (MCE) remote operations via a Satellite Communications (SATCOM) data-link.

FLIR—forward looking infrared: A passive imaging system that senses infrared radiation. The wavelength of infrared that thermal imaging cameras detect differs significantly from that of night vision, which operates in the visible light and near-infrared ranges. (Older USAF Term)

FMRA—FAA Modernization and Reform Act of 2012 (H.R. 658): The law passed to assist with modernizing the nation's aviation system. The law provides funding for the modernization ATC system and allows the FAA to rebuild its ATC system to the next generation technology which will include switching from radar to a GPS ATC system.

FOV—field of view: The extent of the observable world that is seen at any given moment from a sensor onboard the UAS. Depending on the sensor and the camera/display used, there can be more than one FOV.

GAO—General Accounting Office

GCS—ground control station: The station that UAS crews use to control the air vehicle and operate the sensors and systems on board. These stations are sometimes fixed in an office-sized room, and feature a number of computer systems to monitor and control the aircraft. However, GCS may also be an outside location with no enclosure depending on the type of UAS operation. There are also deployable versions of GCSs, meant to be the size and shape of standard shipping containers that can easily fit into a cargo aircraft for transportation.

GDT—ground data terminal: Set of antennas and integrated systems that allow a data-link between the GCS and air vehicle to control and receive feedback and video from the aircraft.

HALE—high altitude, long endurance: A method of classification which classifies UASs in groups based on capabilities. Military HALE vehicles are described as vehicles able to fly above 30,000 feet for more than 24 hours with an operating range over 1,000 nautical miles.

HDD—head down display: Monitors usually located underneath the head up display (HUD) to display engine parameters, link status, electrical load, fuel levels, etc. HDD is any display which is not a HUD.

HUD—head up display: Display projected on the pilot/system operator monitors to allow the operator to fly the UAS. All of the essential information such as altitude, airspeed, attitude, and more are displayed in the HUD. Flying the vehicle can also be accomplished through HDD or Visual LOS (VLOS) control.

ICAO—International Civil Aviation Organization

ILLA—initial lost link altitude: Preprogrammed altitude used in the case of lost data-link between the GCS and the aircraft. If the link is lost, the UAS will automatically assume this altitude and follow preprogrammed contingency procedures awaiting a returned link with the GCS.

ILLH—initial lost link heading: Preprogrammed heading used in the case of lost link between the GCS and the aircraft. If the link is lost, the UAS will automatically assume this heading and follow preprogrammed contingency procedures awaiting a returned link with the GCS.

LALE—low altitude long endurance: A method of classification which classifies UASs in groups based on capabilities. Military LALE vehicles are defined as UASs able to fly up to 10,000 ft. for more than 24 hrs. with an operating range over 200 NM.

LIDAR—light detection and ranging: A remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses—combined with other data recorded by the airborne system—generate precise, three-dimensional information about the shape of the Earth and its surface characteristics. (NOAA 2014)

LL/LL-LOS—loss of link or lost link line-of-sight: A break in connection or loss of connection between the commands given in the GCS and the ability for the UAS to receive and respond to those commands.

LLTV—low light television: A vidicon tube with multiplier tubes that gives a useful picture in near darkness. The system has an excellent night optical capability. This sensor is used mainly to get useful pictures around sunset or sunrise when there is not enough light for a DAY TV and too much for an IR camera.

LOS—line-of-sight: This describes the data-link method of controlling the aircraft. LOS control is often higher quality with direct control and feedback, versus BLOS control which is often accomplished via satellite link and may have a delay. Critical phases of flight, takeoffs, and landings are mostly performed using LOS link for small UAS. To be even more specific, there is visual line-of-sight (VLOS) and Radio Line-of-Sight (RLOS). VLOS provides the opportunity for direct control and feedback. The major difference between VLOS/RLOS and BLOS is higher bandwidth and lower latencies.

LRE—launch and recovery element: The LRE consists of the crews that are responsible for initiating flight and recovering the aircraft. The military refers to it in the following manner: LRE crews are typically experienced mission control element (MCE) crews, as this is treated like an "upgrade" in Air Force UAS programs. The LRE is responsible for the preflight walk-around inspection, landing, taxiing back, and shutting down. The only phase of flight the LRE is generally not responsible for is the mission phase, which is covered by the MCE after "handing-over" control of the aircraft at a predetermined location in air. The LRE is also capable of conducting local line-of-site missions.

LRS—launch and recovery site: The LRS is the site where all of the systems are deployed and all the manpower and equipment are located. Most of the time, this is also where maintenance on the system is performed. Many UAS takeoff and land at an LRS in the same manner as manned aircraft at a runway.

MALE—medium altitude, long endurance: A method of classification that classifies UASs in groups based on capabilities. Military MALE UAS are defined as vehicles able to fly above 20,000 feet, for more than 24 hours, and with an operating range over 200 nautical miles.

MCE—mission control element: For some UAS, the MCE consists of the crews that are responsible for everything outside of the launch and recovery of the aircraft. (MCE is a term used by the military. Most likely the civil growth of UAS will occur in the use of smaller UAS initially; the term may be used or changed as the civil UAS industry grows.)

MPCS—mission planning and control site: Site where the aircraft is controlled during its mission. The MPCS may or may not be collocated with the LRS.

MR—medium range: A category of UAS used by some organizations to designate an aircraft able to fly up to 15,000 feet, for 4 to 8 hours, and with an operating range up to 100 nautical miles.

NAS—National Airspace System: The common network of U.S. airspace; air navigation facilities, equipment, and services, airports or landing areas; aeronautical charts, information, and services; rules, regulations, and procedures; technical information; and manpower and material. Included in the NAS are system components shared jointly with the military.

NASA—National Aeronautics and Space Administration

OPA—optionally piloted aircraft: An aircraft that is integrated with UAS technology and still retains the capability of being flown by an onboard pilot using conventional control methods.

P_f—probability of failure

P/SOW—pilot/sensor operator workstation: Control station inside the GCS from where the pilot or system operator is operating the UAS and its onboard systems and sensors.

PCM—primary control module: The brain of a UAS which processes all the information received and transmitted to the aircraft.

PGCS—portable ground control station: A smaller GCS that can fit into a few suitcases and be set up in a tactical environment or on top of a desk.

PGDT—portable ground data terminal: Same definition as GDT, sometimes smaller in size to allow for ease of transport and to be easily set up in a remote environment.

PIC—pilot-in-command: Crewmember responsible for actual flight of the UAS; additional roles will differ with individual UAS capabilities and missions. All UAS operating in the NAS must have a PIC. PIC is the person who:

- Has final authority and responsibility for the operation and safety of the flight;
- Has been designated as PIC before or during the flight; and
- Holds the appropriate category, class, and type rating, if appropriate, for the conduct of the flight. PIC is a term used by the military. Most likely the civil growth of UAS will occur in the use of smaller UAS initially; the term may be used or changed as the civil UAS industry grows.

RL—return link: When controlling the UAS, the RL is the package of information sent from the aircraft to the GCS containing pictures and metadata.

RLOS—radio line-of-sight

ROA—remotely operated aircraft

RPA—remotely piloted aircraft

RPAS—Remotely Piloted Aircraft System

RPV—remotely piloted vehicle. ROA, RPA, RPAS, and RPV are all used synonymously for an aircraft which is unmanned. ROA and RPV are no longer used in most segments of the industry.

RSO—remote split operations: RSO are conducted when the LRS and the MPCS are not col-located. Some UAS are equipped with SATCOM, and missions can extend beyond line-of-sight or over the horizon. These missions are flown from a geographically separated, or remote, GCS. When conducting RSO, the LRS will launch the aircraft and hand over controls to the MPCS at a predetermined point in the air. Upon mission completion, the MPCS will then return the aircraft to a predetermined location where the LRS will take control and land the aircraft.

SAA—sense and avoid: The capability of a UAS to remain well clear from and avoid collisions with other airborne traffic. Sense and avoid provides the functions of self-separation and collision avoidance to establish an analogous capability to "see and avoid" required by manned aircraft.

sUAS—Small Unmanned Aircraft System: An unmanned aircraft weighing less than 55 pounds and operated within VLOS below 400 feet. Other restrictions also apply.

SO—sensor operator: The SO, if required, is primarily responsible for the operation of the UAS payload. Additionally, this crewmember is responsible for backing up the pilot/operator on monitoring aircraft engine, electrical, and data-link systems during most phases of flight. The SO is also responsible for reading checklists to the pilot in normal and emergency situations. The SO primarily focuses on mission execution—tracking targets and reporting with other agencies on information, intelligence, and surveillance findings; and monitoring flight path for de-confliction with weather, terrain, and other aircraft during the MCE phase. SO is a term used by the military. Most likely the civil growth of UAS will occur in the use of smaller UAS initially; the term may be used or changed as the civil UAS industry grows.

UA—unmanned aircraft:

- A device used or intended to be used for flight in the air that has no onboard pilot. This device excludes missiles, weapons, or exploding warheads, but includes all classes of airplanes, helicopters, airships, and powered-lift aircraft without an onboard pilot. UA do not include traditional balloons (see 14 CFR Part 101), rockets, tethered aircraft, and unpowered gliders.
- An aircraft that is operated without the possibility of direct human intervention from within or on the aircraft.

UAS—Unmanned Aircraft System: An unmanned aircraft and its associated elements related to safe operations, which may include control stations (ground, ship, or air-based), control links, support equipment, payloads, flight termination systems, and launch/recovery equipment.

An unmanned aircraft and associated elements (including communications links and the components that control the unmanned aircraft) those are required for the PIC to operate safely and efficiently in the NAS.

UAV—unmanned aerial vehicle: An unmanned aerial vehicle, commonly known as a drone, is an aircraft without a human pilot on board. Its flight is controlled either by computers in the vehicle, or under the remote control of a pilot on the ground or in another vehicle. There are a wide variety of drone shapes, sizes, configurations, and characteristics. Historically, UAVs were simple RPA, but onboard control is increasingly being employed. (*Note: this term is no longer widely used in the industry; however, when searching for information on unmanned aircraft, using UAV may still lead to useful information.*)

UL—up link: UL is the package of information sent to the aircraft from the GCS to control it.

UMS—Unmanned System

UVSI—Unmanned Vehicle Systems International

VLOS—visual line-of-sight

E-2 Glossary of Key Terms

Autonomous Flight—Set of equipment/computers, and internal navigation systems (INS) GPS navigation units which allow a UAS to navigate and fly autonomously. Autonomous flight generally means the vehicle is capable of reasoning and decision making without oversight or intervention from human controllers, a level of autonomy that is not presently contained in most UAS.

C-Band—Frequency band selected and used by a UAS system to operate an aircraft from its control station when in line-of-sight. C-Band is from 4GHz to 8GHz and is one of several bands used to control UAS.

Civil Aircraft—Aircraft other than public aircraft (public aircraft include military and other government-use aircraft). Civil aircraft include those which are privately owned such as general aviation (GA) aircraft governed by 14 CFR Part 91, and those operated for commercial purposes such as those which fall under 14 CFR Part 121 and 14 CFR Part 135 operations.

Class A Airspace—Generally, airspace from 18,000 feet MSL up to and including FL 600, including the airspace overlying the waters within 12 nautical miles of the coast of the 48 contiguous states of the United States and Alaska. Unless otherwise authorized, all persons must operate their aircraft under Instrument Flight Rules (IFR) in Class A airspace.

Class B Airspace—Generally, airspace from the surface to 10,000 feet MSL surrounding the nation's busiest airports having very high numbers of airport operations or passenger enplanements. The configuration of each Class B airspace area is individually tailored and consists of a surface area and two or more layers (some Class B airspace areas resemble upside-down wedding cakes), and is designed to contain all published instrument procedures once an aircraft enters the airspace. An ATC clearance and two-way communication is required for all aircraft to operate in the area, and all aircraft that are so cleared receive separation instructions within the airspace.

Class C Airspace—Generally, that airspace from the surface to 4,000 feet above the airport elevation surrounding those airports that have an operational control tower, are serviced by a radar approach control, and have a certain number of IFR operations or passenger enplanements. Although the configuration of each Class C area is individually tailored, the airspace usually consists of a surface area with a five nautical mile (NM) radius, a circle with a 10 NM radius that extends no lower than 1,200 feet up to 4,000 feet above the airport elevation, and an outer area that is not charted. Each person must establish two-way radio communications with the ATC facility providing air traffic services prior to entering the airspace, and thereafter maintain those communications while within the airspace.

Class D Airspace—Generally, airspace from the surface to 2,500 feet above the airport elevation surrounding those airports that have an operational control tower. The configuration of each Class D airspace area is individually tailored and when instrument procedures are published and the airspace will normally be designed to contain the procedures. Arrival extensions for instrument approach procedures may be within Class D or Class E airspace. Unless otherwise authorized, each person must establish two-way radio communications with the ATC facility providing air traffic services prior to entering the airspace and thereafter maintain those communications while in the airspace.

Class E Airspace—Generally, if the airspace is not Class A, Class B, Class C, or Class D, and it is controlled airspace, it is Class E airspace. Class E airspace extends upward from either the surface or a designated altitude to the overlying or adjacent controlled airspace. When designated as a surface area, the airspace will be configured to contain all instrument procedures. Also in this class are federal airways, airspace beginning at either 700 or 1,200 feet AGL used to transition to/from the terminal or en route environment, en route domestic, and offshore airspace areas designated below 18,000 feet MSL. Unless designated at a lower altitude, Class E airspace begins at 14,500 MSL over the United States, including that airspace overlying the waters within 12 NMs of the coast of the 48 contiguous states and Alaska, up to, but not including 18,000 feet MSL, and the airspace above FL 600.

Class G Airspace—That airspace not designated as Class A, B, C, D or E.

> **Note for Airspace definitions:** There are also minimum equipment requirements for aircraft to operate in each class of airspace. This in many ways can be a limiting factor to UAS operators. (FAA 2014d)

Collision Avoidance—The sense and avoid (detect-and-avoid) system function where the UAS takes appropriate action to prevent an intruder from penetrating the collision volume. Action is expected to be initiated within a relatively short time horizon before the closest point of approach. The collision avoidance function engages when all other modes of separation fail. (See SAA; see DAA)

Communication Link—The voice or data relay of instructions or information between the UAS pilot and the ATC and other NAS users. It is generally understood that there are two possible communication links; one from the UAS operator to/from the vehicle and the other from the payload operator to/from the vehicle.

Control Station—The equipment used to maintain control, communicate with, guide, or otherwise pilot an unmanned aircraft. The control station includes the communications equipment, computers, control inceptors, and displays used to control the vehicle as well as the physical enclosure, support systems, and power sources.

Crewmember [UAS]—In addition to the crewmembers identified in 14 CFR Part 1, a UAS flight crewmember includes pilots, sensor/payload operators, and visual observers, but may include other persons as appropriate or required to ensure safe operation of the aircraft.

Data-link—Typically, a ground-to-air communications system that transmits information via digital coded pulses. However, data-link can also be air-to-air, ground-to-ground, and ground-to-space.

Lost Link—Describes the state of the aircraft when it has no communication with ground control. Once the link is lost, the operator is no longer in control of the airplane until link is regained. In the event of lost link, the UAS executes preprogrammed lost link procedures, which can be loaded prior to takeoff or during flight depending on the type of UAS. The aircraft will strictly follow the procedures preprogrammed by the operator. A few examples of lost link procedures are listed below:

- Fly to the recovery field
- Fly to a specific set of coordinates using GPS
- Take any action it was preprogrammed to take (such as flight termination).

Model Aircraft—An unmanned aircraft that is capable of sustained flight in the atmosphere; flown within visual line-of-sight of the person operating the aircraft, and flown for hobby or recreational purposes.

Narrow Beam Antenna—High gain antenna with a focused narrow sector for a long distance.

OMNI Antenna—Omnidirectional antenna that sends and receives signals equally in all directions.

Operator—Under the proposed FAA rule for small UAS, pilots of a small UAS will be considered operators.

Payload—Set of sensors and cameras carried on board a UAS.

Public Aircraft—An aircraft operated by a governmental entity (including federal, state, or local governments, and the U.S. DOD and its military branches) for certain purposes as described in 49 U.S.C. §§ 40102(a)(41) and 40125. Public aircraft status is determined on an operation by operation basis. See 14 CFR Part 1, § 1.1 for a complete definition of a public aircraft.

Public Aviation—Public Aircraft Operation (PAO) is limited by statute to certain government operations within U.S. airspace. Although these operations must comply with certain general operating rules (including those applicable to all aircraft in the NAS), other civil certification and safety oversight regulations do not apply. Whether or not an operation may be considered public is determined on a flight-by-flight basis, under the terms of the statute (49 U.S.C. 40102 and 49 U.S.C. 40125) and depends on factors such as aircraft ownership, operator, the purpose of the flight, and the persons on board the aircraft.

SATCOM—Satellite communications: Term used to describe controlling the aircraft in BLOS using a satellite system and equipment.

Section 333 Exemption—By law, any aircraft operation in the national airspace requires a certificated and registered aircraft, a licensed pilot, and operational approval. Section 333 of the

FAA Modernization and Reform Act of 2012 grants the Secretary of Transportation the authority to determine whether an airworthiness certificate is required for a UAS to operate safely in the NAS. This authority is being leveraged to grant case-by-case authorization for certain unmanned aircraft to perform commercial operations prior to the finalization of the Small UAS Rule, which will be the primary method for authorizing small UAS operations once it is complete. The Section 333 Exemption process provides operators who wish to pursue safe and legal entry into the NAS a competitive advantage in the UAS marketplace, thus discouraging illegal operations and improving safety.

Self-Separation—Sense and avoid system function where the UAS maneuvers within a sufficient timeframe to remain clear of other airborne traffic.

Sensor—Set of equipment that can be installed on board the UAS for the purpose of information gathering.

Special Airworthiness Certificate–Experimental Category (UAS)—Airworthiness certification for a civil experimental UAS. The FAA defines the Experimental Category as follows: A special airworthiness certificate in the experimental category is issued to operate an aircraft that does not have a type certificate or does not conform to its type certificate and is in a condition for safe operation. Additionally, this certificate is issued to operate a primary category kit-built aircraft that was assembled without the supervision and quality control of the production certificate holder.

Test Range—A defined geographic area where research and development are conducted. Test ranges are also known as test sites in related documents, such as the FAA's Screening Information Request.

Visual Line-of-Sight—Unaided (corrective lenses and/or sunglasses exempted) visual contact between a pilot-in-command or a visual observer and a UAS sufficient to maintain safe operational control of the aircraft, know its location, and be able to scan the airspace in which it is operating to see and avoid other air traffic or objects aloft or on the ground.

Wide Antenna—Directional antenna, perhaps on a UAS ground data terminal, which sends and receives signals equally distributed in a wide sector of interest with a variety of ranges that are specific to the operation.

APPENDIX F

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Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TDC	Transit Development Corporation
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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