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WIDE-SCALE SMALL UNMANNED AIRCRAFT SYSTEM ACCESS TO THE NATIONAL AIRSPACE SYSTEM

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Expected revisions of federal policies and regulations for the operation and certification of small unmanned aircraft systems (sUAS) are anticipated to significantly increase the volume of traffic in the National Airspace System (NAS). By investigating critical needs of regulatory compliance and safety, as well as new advancements, it may be possible to identify strategies to address the most pressing concerns of sUAS integration. Findings and recommendations from this research are presented to highlight implications and possible solutions to urgent needs of UAS stakeholders, including industry, government, and academia.

INTRODUCTION

Once implemented, impending revisions of federal policies and regulations for the operation and certification of small unmanned aircraft systems (sUAS) are anticipated to significantly increase the volume of traffic in the National Airspace System (NAS). While interest and potential benefits of sUAS technology has grown significantly, the challenges and limitations of wide-scale operations require examination to gain critical insight of needs and potential strategies to achieve regulatory compliance and increased safety. Exploration of alternative technologies, methods, and processes may hold the keys to addressing some of the most pressing concerns, such as detect, sense, and avoid limitations; airspace and infrastructure security; improved public outreach; establishment of training and certification standards; and delivery of operator certificate testing.

This research consisted of investigation, analysis, and discussion of such advancements, as they relate to continued maintenance of safety, efficiency, and effectiveness within the NAS. A systematic and critical review of literature, including current sUAS-related research and documented performance capabilities, were conducted to ascertain the state of preparedness for anticipated users to meet identified requirements of certification and operation. Findings and recommendations are presented to highlight implications and possible solutions to urgent needs of UAS stakeholders, including industry, government, and academia.

BACKGROUND

The primary inhibitor of sUAS adoption in the U.S. is the range of regulatory restrictions that exist. The proliferation of the UAS industry has been suppressed by the various requirements of the Federal Aviation Administration (FAA), states, and, in some cases, local governments. The exceptions to this are a limited number of users who have gone through the application processes

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in place to allow for exemptions or special operating authorizations. For the most part, these occurrences have been limited to academic and research users as well as larger-scale commercial operators who have the most to gain from the investment of time, money, and personnel to pursue such processes.[1] While the FAA has relaxed some of the bureaucratic obstacles for more mainstream access, the overall numbers of authorized operators is relatively small with respect to the numbers of UAS either already purchased or the numbers expected to soon be flying.[2]

UAS Regulations and Policies

Since the FAA Modernization and Reform Act of 2012, the agency has been instructed to take action by Congress to foster the integration of UAS into the NAS no later than September 2015. Initially, the actions of the FAA towards this goal were limited and the overall UAS operational options were highly restricted. Since late 2013, the FAA has moved to relax its obstructive stance. As of March 2016, the FAA no longer requires specific approval or exemption for recreational or hobby use of sUAS weighing less than 55 pounds as long as the device is heavier than 0.55 pounds and are registered through the FAA's new UAS registration portal.[3] For those outside the recreational or hobby realm, e.g. non-governmental commercial operations, specific approval is mandated. Currently, there are four means to receive authorization for such operations: Special Airworthiness Certificates – Experimental Category (SAC-EC), Restricted Category UAS type and airworthiness certificates, civil Certificate of Waiver Authorization (COA), or petition for a Section 333 exemption. For those seeking more flexibility, the Section 333 exemption comes with a blanket COA authorizing operations below 400 feet (not including certain activities such as operations near or on airports or over populated areas). For government or public UAS operation, a separate COA process must be pursued.[4]

By early 2015, the FAA announced their plan to create a new set of regulations specific to sUAS, Part 107. This proposed regulatory guidance proposes to make sUAS operations more accessible and flexible. Operators would be required to take a knowledge test as well as to be vetted by the Transportation Security Administration. Recurrent training would be required every 24 months. The FAA would issue unmanned aircraft operator certificates with a sUAS rating. Operators would not be required to have an airworthiness certificate for their sUAS but would have to perform preflight inspections as well as to be responsible to maintain the platform in airworthy condition. All sUAS would be subject to registration and markings requirements. Also, sUAS operations would be subject to specific restrictions such as remaining in visual line of sight (VLOS), flying only during daylight hours, avoiding aircraft, remaining outside controlled airspace unless specifically authorized, and never to conduct operations deemed careless or reckless.[5]

Additional concerns and restrictions may exist at the state and local levels. There are currently more than 20 states with active or passed bills restricting the use of UAS. Additionally, a number of municipalities have passed regulations on UAS flights and, in some cases, created "no drone zones".[1] Certain entities and business have done the same.[6] Other ongoing concerns involve privacy. While the FAA has provided limited guidance on this issue, it does advocate for operators to develop privacy management plans for their operations. While existing case law sets a precedent for government surveillance via UAS, what remains unknown is how private users may be subject to liabilities for intended or unintended abuse of personal privacy through data collection during flight activity. Also unresolved is the rights of sUAS operators to fly over or around properties of other individuals. It is envisioned that this will eventually be resolved in court decisions as sUAS become more commonplace.[1]

State of Industry

Even in light of the hampered growth of sUAS application in the U.S., the current state of the industry is promising and expected to continue to grow, perhaps exponentially, when regulations are finalized. It is important to note that even in countries with more flexible operational rules, growth in sUAS utilization has been measured. Currently, the commercial UAS market has focused on agriculture, utilities, real estate, photography/cinematography, news media, and research. Although e-commerce and package delivery using UAS has received much media attention, it is not expected to become reality for some time, at least not until key technical issues remain unresolved such as sense and avoid as well as integration of UAS with manned aircraft. The expected global compound annual growth rate (CAGR) for UAS is 19% from 2015 to 2020.[7] It is anticipated that sUAS operations will become much more common, albeit highly restricted, by 2017, following the finalization of Part 107 and other associated regulation changes. The global UAS market value is approximated to be $1.5 billion with a projected growth to over $3.5 billion by 2024.[7] Other groups, such as AUVSI, predict larger impacts including $82 billion in economic impact and over 100,000 new jobs.[8]

As of September 2015, the FAA reported that over 1,400 Section 333 exemptions were in place for commercial use. The agency processes approximately 50 such exemptions per week as the industry continues to develop. The primary utilization of these exemptions is data gathering with the largest numbers of operators in California, Texas, and Florida. The California Bay Area is especially active, with many of the domestic leaders of UAS (DroneDeploy, 3D Robotics, and Skycatch) being situated in that locale. Primary usage across the U.S. is in agricultural applications, real estate surveying, as well as general aerial data observation/data collection. Interestingly, the overwhelming majority of 333 exemption holders are small businesses, with larger companies reserving their operations to countries with less restrictive operating environments such as Canada and Australia. It is imaged that such operations could be brought back to the U.S. once regulatory and compatibility matters are resolved. Many businesses are still waiting for the FAA's final ruling to pursue UAS adoption. Again, it is envisioned that growth will accelerate once the operational guidance is solidified.[8]

SUAS OPERATIONAL CHALLENGES

There are a number of technical and operational challenges that must be met to satisfy equivalent safety in the application of sUAS, as compared to manned aircraft. Areas where the need of such equivalency is most apparent include detect, sense, and avoidance (DSA); availability and security of airspace and infrastructure; and public awareness. The following contain detailed discussion regarding the challenges of ensuring safety in application of sUAS as related to each of these respective areas.

Detect, Sense, and Avoid

Detect, Sense, and Avoid (DSA) represents the consolidation of sense and avoid (SAA) and detect and avoid (DAA) concepts, methods, and mechanisms and is a topic of critical importance to ensure de-confliction among manned and unmanned aircraft operating in the NAS. While the performance of remote visual sensory capture instruments (e.g., cameras and other sensors) continues to increase,[9,10] the limited field of view (FOV) and capability to transmit real-time video imagery to an operator results in reproduction fidelity less than human optical perception. For this reason, such equipment has been deemed insufficient to meet see-and-avoid requirements of current regulations and practices for beyond visual line of sight (BVLOS) UAS operations.[11]

Alternative and supplemental methods are being developed and evaluated to augment interaction and increase the reproduced visual fidelity, interoperability of data sharing, and overall situational awareness among operators, manned pilots, and air traffic control (ATC) personnel. Onboard, ground-based, and multi-nodal communication solutions, which when used in combination (i.e., cooperative information sharing) , may increase the potential for positive identification, tracking, and collision avoidance.[12] Onboard UAS options for supporting improved DSA include the capture of remote environmental data using exteroceptive sensors exceeding human perception (e.g., radar, ranging, and imaging), machine-vision and three-dimensional visual processing, adaptable localization and navigation mechanisms (sensor fusion and dead-reckoning), and transmission source detection with orientation and distancing determination.[9,13,14,15]

Ground-based DSA options consist of active and passive sensing, as well as visual, aural, and signal transmission detection and processing to determine the distance, trajectory, and path of aircraft in the vicinity of the sensing apparatus. Both ground-based and onboard options can further be supplemented using beacon transmission and receipt monitoring (e.g., propagation-signal strength or pathway alignment), as well as coordinated communications, such as procedural communication and automatic communication among operational parties (e.g., Automatic Dependent Surveillance-Broadcast [ADS-B], Traffic Alert and Collision Avoidance System [TCAS], and ground-based or aerial ad-hoc networks).[16,17,18] Integration of data from multiple sources increases the fidelity and accuracy of environmental models, in turn supporting improved DSA, path planning, and collision avoidance, whether through procedural de-confliction (e.g., visual observation or ATC management) or automatic control response.[11,12,19]

Airspace and Infrastructure Integrity

The operation of sUAS in the NAS, among cooperative and non-cooperative, present several substantial issues that must be addressed before routine operations will be achievable at an equivalent level of safety, as exists currently. The technological and procedural advances stemming from DSA, as well as improved understanding of unmanned aircraft operational capabilities and requirements, are driving the creation of new infrastructure and operational methods to support increased and eventual routine operations. As previously discussed, new operational rules governing use and oversight have been proposed, with a pathway established for revision based on the evolutionary nature of technology and envisioned use.

While there are substantial issues affecting wide-scale operations, including airspace congestion, availability of frequencies for command, control, and communication (C3), communication integrity, infrastructure availability and security, and manned pilot distraction,[20,21] R&D developments are exhibiting promising potential to provide possible solutions. Limited operational detection and tracking of compliant and non-compliant aircraft has been accomplished, a robust conceptual model for management of operations has been developed, and multiple technologies have been integrated with computational processing to confirm positive identification. Existing ATC terminals have been upgraded with ground based sense and avoid (GBSAA) capabilities to enhance the situational awareness of UAS operators and ATC personnel, eliminating the need for visual observers during the transition between Class D and restricted airspace.[22] It has been surmised that the addition of new radar equipment could provide enhanced coverage to identify and track non-cooperative aircraft and support wider UAS operations within the NAS.[22]

The National Aeronautics and Space Administration (NASA) has continued to work on a UAS Traffic Management (UTM) system, with the support of industry stakeholders such as Google, Amazon, Verizon, Airware, and the Association of Unmanned Vehicle Systems International (AUVSI), to manage routine operations below 500 feet above ground level (AGL), among other

aircraft, in either VLOS or BVLOS operational profiles .[23,24] Their current model supports the incorporation of environmental characteristics and other operational constraints, such as actual and predicted weather; UAS platform performance; reservation of airspace; and tracking using multiple sources (e.g., ADS-B, cellular, and satellite).[25] One novel aspect being considered under the evolving UTM design is the potential use of cellular communications infrastructure to provide monitoring, data networking, and navigation.[23] The eventual incorporation of such an airspace management model and associated technology may assist in making sUAS operations among manned aircraft safer, while also increasing efficiency and effectiveness by defining the permissible operational scope of specific platforms within known environments.

Another significant concern is the potential security of infrastructure and safety of manned aviation, which are at risk from unintentional violations from operators, unaware of operation requirements and provisions, as well as those seeking to do intentional harm with malicious intent.[20,22,26] Positive detection and tracking of sUAS can provide the opportunity to prevent malicious actions, such as smuggling, espionage, or terrorism.[26] Technology and processes have been developed to enable the positive identification of sUAS using seismic, acoustic, visual, return-signal emission, and radio transmission detection sensing, coupled with computational processing.[20,26,27] sUAS platforms are also susceptible to malicious intent from those on the ground through hacking, jamming, spoofing, monitoring, and attack.[20] Some of these methods are being adapted by federal authorities, researchers, and private enterprises to serve as countermeasures in the prevention of potential security risks, while others are pursuing for illegal purposes. With reports of sUAS inappropriately operating within close proximity to airports and aircraft exceeding 100 per month[27] and observed cases of attempted smuggling of contraband into correctional facilities, it is apparent that DSA advances are necessary to counteract lack of public awareness regarding permissible, as well as intentional illegal use.[20,28]

Public Education

To date, exact requirements and standards for the development and delivery of sUAS training and certification have not been released by federal sources. However, current provisions for the operation of sUAS require registration of the aircraft and operator, with recreational operators registering individually and non-recreational registering aircraft, operator certification, and operational approval (e.g., Public or Civil Use COA). A significant issue affecting safety is the lack of awareness regarding permissible recreational operations. Compounding the issue is the wide-scale availability of platforms, affordable price-point, and rapidly increasing operational capabilities and complexity.[29] Several efforts have been undertaken to reach and educate this segment of the community to the legal requirements of recreational operation, including through web-based, multimedia, and software mediums.

The FAA, AUVSI, and the Academy of Model Aeronautics (AMA) launched the *Know Before-You Fly* campaign, including an associated website featuring guidance for recreational, commercial, and public agency users, an airspace lookup and reference tool, frequently asked questions, and links to other resources, including the sUAS Registration Service.[30,31] In support of enhancing safety, the FAA has also developed several resources to help users better understand where permissible operations can be conducted. These resources include the "I Fly Safe" checklist, "No Drone Zone," and B4UFLY smartphone app (iOS and Android).[32,33,34]These efforts have been further bolstered by the previously established AUVSI "Code of Conduct" and AMA "Safety Code",[35,36] as well as focused campaigns, such as the recent U.S. Department of Agriculture's "If You Fly, We Can't"[37] (avoiding sUAS operation during active emergencies) and the National Agriculture Aviation Association's "UAV Safety Education Campaign".[35,36,37,38] These efforts have been well re-

ceived, but require further visibility among non-aviation adopters of sUAS to ensure they are successful in their goal of educating the public regarding when, where, and how the technology can be used in a safe, responsible, and appropriate manner.

DISCUSSION

With any evolving industry comes the requirement to implement changes to existing infrastructure and evaluate policy and regulation concurrently. In order for any group or classification of unmanned aircraft to integrate safely into the NAS, a number of expectations must be set in place that are heavily assumed by individual operators. Landmark changes to UAS operations have taken place over a short span of time due to projections that many UAS will be sold and operated in the NAS with minimal regulation. The FAA began requiring registration of operators for hobby/recreational use aircraft (.55 to 55 pounds) in December of 2015 and now estimates that 2.5 million such aircraft are in operation with the potential for a total of seven million by 2020.[39] The notion of such a high volume of aircraft could induce potential negative effects from users who may have limited aeronautical experience, which cause for a high level of concern. The improper or irresponsible use of aircraft, especially in terminal environments, may significantly impact safety, public perception, and public bias toward future unmanned aircraft operations.

The FAA is proactively addressing many issues that may impede safe UAS operations by working with academia, manufacturers, and others in government to determine requirements for airworthiness, operational limitations, training and certification, maintenance and incident reporting, and many other focus areas that must be addressed prior to full-scale integration. Technology developments associated with ADS-B and improved sensing (e.g., LiDAR) may provide reasonable solutions to manage or lower the probability of aircraft incursions, while a host of other sensors may enhance remote-sensing capabilities. As the miniaturization of technology continues to flourish and cost becomes less premium for UAS components, operator's will have more potential to enter into industry with unique solutions to both existing and potential problems.

Many potential issues become apparent in review of operator experience, training, and knowledge. A number of aircraft that are categorized by regulation as sUAS are sold to the general public with little to no prior training or registration requirements. The danger in this process is that potential UAS operators may not see the importance of acquiring knowledge, skills, and abilities (KSAs) essential to safe operations in the NAS and among other aircraft. The FAA, along with stakeholders are aggressively working to define airman practical test standards, airman certification requirements, and training elements necessary to confirm operational preparedness and comprehension in all environments. It is the responsibility of UAS operators to act in a way consistent with regulation, which will foster a positive safety culture through awareness and accountability. These efforts will allow industry to embrace technologies as they become available in an effort to expand the envelope of UAS potential.

CONCLUSIONS

With better definition of FAA rules and regulations, the ability to feel more confident about the future uses of sUAS in the NAS will start to manifest with UAS developers being able to design, test and implement new technologies in a more robust manner. The technology needed to overcome many UAS operational challenges has been present for a number of years, but due to extreme restrictions on the use of operational units within the NAS, lack of FAA guidance concerning use of UAS in the NAS, and government restrictions on export of this type of technology outside of the U.S., development, test and evaluation of those technologies by companies has been greatly hampered. Development and refinement of DSA technologies for manned, unmanned, and ATC will be critical as UAS, and specifically sUAS, begin to grow and proliferate in the near future.

Understanding how, when, and where the future capabilities of UAS platforms and technology can legally be used will foster a high degree of implementation and integration of this technology into every aspect of society. New technology and infrastructure will need to be developed and integrated into the NAS that may not have been previously anticipated to maintain and enhance current levels of safety when combined with manned platforms and technology. The inclusion of UAS into the NextGen framework is underway and many changes designed to enhance safety and situational awareness have already been integrated into ATC systems. It is conceivable that as uses for sUAS platforms increase, and development of more capable technologies evolve, significant revision of some sections of NextGen implementation may need to be considered. The main goal of the NextGen effort is to upgrade technology and infrastructure to meet the demand of the expanding aviation industry while maintaining and enhancing safety.

As the FAA moves forward in its effort to safely integrate sUAS into the NAS, it must be keenly aware of new challenges and new technology that can be employed to achieve the equilibrium needed between safety, efficiency, and the needs of the rapidly changing UAS industry. As access to the NAS becomes more attainable, maximization of entrepreneurial aspiration, scientific ingenuity, and safety and security of the general public must remain primary concerns moving forward.

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