An Overview of Unmanned Aircraft System Integration

Within the National Airspace System

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Abstract

Unmanned aircraft systems have evolved rapidly in recent years. This evolution involves the development of UAS applications that many experts did not anticipate ever occurring. This evolution has left regulatory bodies with a wide gap between the technology available and the regulation, procedures, and documentation to regulate and manage it. The Federal Aviation Administration is the United States' lead government organization in the effort to integrate this technology into the National Airspace System. Many government and industry organizations are working with the FAA on this task, which includes the execution of research and development projects. The FAA and its partners are also working with international governments and organizations to harmonize global requirements. Significant progress has been made toward this integration, but there is an extensive amount of research and development that must occur to reach full integration.

An Overview of Full Unmanned Aircraft System Integration

Within the National Airspace System

Unmanned aircraft systems (UAS) are a fantastic addition to technology that has revolutionized the world in the past decade. The evolution of UAS could benefit most members of society, and they have already had a significant impact. There are several instances of UAS saving lives through search and rescue operations or making medical deliveries more efficient (Shao, 2022; Silvagni et al., 2017).

Goldman Sachs (2022) predicts that by 2030 the global UAS market will be worth over 100 billion dollars. In 2022, the commercial UAS market was estimated to be worth $58.4 billion (Zoldi, 2022). This is an astounding rate of growth, considering that in 2015 the entire market was worth $5.93 billion (Diamond, 2022). These numbers alone show the massive potential of the UAS industry. The significant revenue that UAS have made allows for further investment into this industry's research and development (R&D). This helps fuel the tremendous growth that has been happening within the world of UAS.

UAS integration involves the development of technologies, regulations, policies, standards, and best practices (to name a few factors) that are required for these systems to operate safely and efficiently within the NAS (FAA, 2022). With the current level of integration, lives are being saved and billions of dollars are being made, so further integration into the NAS would only expand these benefits (Vanderhorst et al., 2019). There are many challenges and areas of development that must be addressed before full integration is possible. Some of the leading research areas that must be addressed are Remote Identification, Detect-and-Avoid, Command and Control, Human Factors, Forecasting, and UAS Studies (FAA, 2020). These areas must be addressed before the FAA can expand the regulations surrounding UAS to allow for more complex operations.

Background

Definition of a UAS

The FAA (2022) defines a UAS as the following:

> An unmanned aircraft system is an unmanned aircraft and the equipment necessary for the safe and efficient operation of that aircraft. An unmanned aircraft is a component of a UAS. It is defined by statute as an aircraft that is operated without the possibility of direct human intervention from within or on the aircraft. (para. 1)

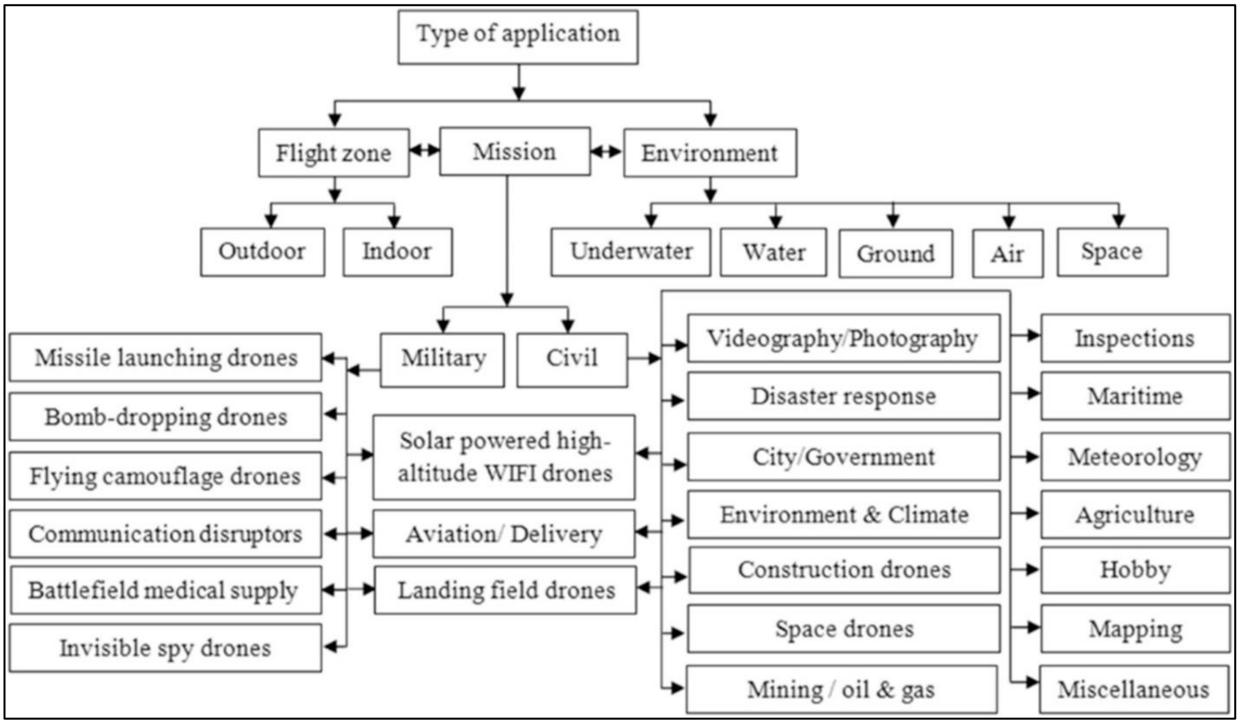
This definition shows that a UAS is not simply the aircraft in the sky but includes the entire system used to control that aircraft. An aircraft can also be considered unmanned if there is a person within the aircraft if that person has no possibility of intervention or control of the aircraft.

UAS Roles

Unmanned Aircraft Systems (UAS) are rapidly fulfilling more roles than anyone in the past could have imagined. Researchers Hassanalian and Abdelkefi (2017) show that UAS are capable of fulfilling a vast number of roles because of their adaptability. Figure One shows a flowchart that they created listing many of the applications that UAS are being used for. This chart does not even include the impact of some of the larger possible UAS applications, such as delivery and passenger transportation. Some of the most well-known applications are drone delivery, warfare, surveillance, inspections, and photography/ videography. This massive list of applications is constantly shifting and growing, but it shows the significant impact that UAS can have on the world.

Figure 1

UAS Applications Flowchart (Hassanalian & Abdelkefi, 2017)



UAS are fulfilling roles in many industries that used to be either difficult or dangerous to fill. One survey within the United States construction industry stated that UAS are having exponential growth within this field because it gives workers a method of inspecting or monitoring an area that previously may have been too small or too dangerous to put a worker in (Albeaino & Gheisari, 2021). UAS are also increasing safety in many other industries. Unmanned vehicles are safer than manned vehicles for fighting wildfires simply because they take the manned pilot out of the scenario (Ghamry et al., 2017). This same logic could be applied to any industry with high-risk manned aviation roles such as crop-dusting or military operations. Having no pilot in an aircraft dramatically reduces the risk of loss of life as long as any possible crash is made in an unpopulated area.

Safety and working conditions are not the only reason that UAS are beginning to fill a large number of roles. A significant factor contributing to the popularity of UAS is their economic sustainability for specific roles. One excellent example of this is the delivery industry. A significant topic within the delivery industry is the last mile. The last mile is the most expensive part of every delivery (Ranieri et al., 2018). Aurambout et al. (2019) explain that the UAS industry could be an excellent solution to the dilemma that delivery businesses face with the last mile dilemma. This technology has been successfully developed and demonstrated in several locations around the globe. One Irish food delivery company, Manna, is performing over two thousand delivery flights a day, and they report that their deliveries are approximately 10% of the cost that they would be if they were standard car deliveries. Their deliveries are also much quicker than standard deliveries because of the flight path these UAS can take.

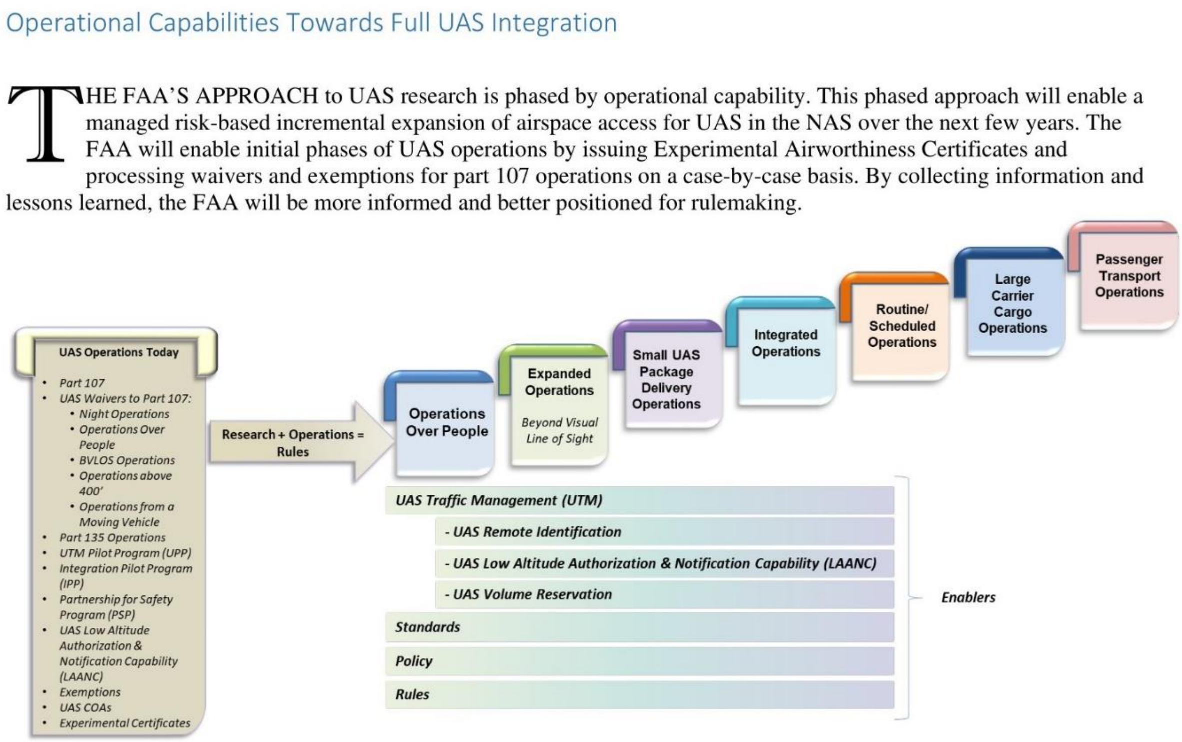
FAA's definition of Full integration into the NAS

Operational Capabilities

The FAA has established a seven-step process toward full integration within the NAS (FAA, 2022). Figure Two shows an FAA diagram of these steps. These steps are called operational capabilities. Each of these capabilities has many steps that must be accomplished to make them possible. Full integration has been reached when each of these capabilities is achieved. These operational capabilities were selected by taking input from industry partners to determine what advancements would help advance the industry the most. These capabilities, their definitions, and the steps to accomplish them can be found in the FAA's Unmanned Aircraft Systems Research (A11L) Research Plan: 2022-2027 (2022). These capabilities will be achieved in sequential order, and they are ordered based on their complexity and the demand from the industry. Research for each of these capabilities is being performed in parallel, so achievements toward one capability can be used to advance others. The following is a description of the UAS operational capabilities.

Figure 2

(FAA, 2020, p. 25)


Operational Capabilities Towards Full UAS Integration

THE FAA'S APPROACH to UAS research is phased by operational capability. This phased approach will enable a managed risk-based incremental expansion of airspace access for UAS in the NAS over the next few years. The FAA will enable initial phases of UAS operations by issuing Experimental Airworthiness Certificates and processing waivers and exemptions for part 107 operations on a case-by-case basis. By collecting information and lessons learned, the FAA will be more informed and better positioned for rulemaking.

Operations Over People. The operational capability of operations over people has already been accomplished, but it may continue to progress in the future (FAA, 2020). With the current level of traffic management and regulation, operations over people are not always allowed, but there are methods and guidelines for those that want to operate over people. This operational capability has allowed far more commercial UAS activities and is greatly helping the industry as a whole.

Expanded Operations. Expanded operations are based on leveraging previously made regulations to help enable beyond visual line of sight (BVLOS) operations and operations over people. Some expanded operations have already taken place, but the FAA wishes to make these operations more available to users with a less complex and time-consuming waiver process to perform them (FAA, 2021).

Small UAS Package Delivery Operations. SUAS package delivery operations will allow a fleet operator to deliver large numbers of packages using SUAS within the NAS. The FAA is working with partners to develop the technology and management to make these systems possible. These experiments have proven successful in trial runs, but for more widespread operations to occur, several challenges must be overcome; these will be discussed later (FAA, 2020).

Integrated Operations. Integrated operations involve the combination of manned and unmanned traffic operating in the same airspace. This integration includes public and civil aircraft of varying sizes and altitudes with operations in airport environments. These unmanned aircraft will also be capable of flying on instrument flight plans. This will require a much higher level of Unmanned Traffic Management (UTM) than is currently in place, but it will significantly expand the number of opportunities for UAS to benefit society (FAA, 2020).

Routine/Scheduled Operations. Routinely scheduled operations will allow UAS to have safely scheduled arrivals and departures at airports of all sizes. This unmanned traffic will also coordinate with the Advanced Air Mobility (AAM) traffic. AAM traffic will consist of UAS that routinely transport cargo and passengers through rural, suburban, and urban environments. With routine operations, air traffic control (ATC) management will be available to any UAS pilot that files an instrument flight plan (FAA, 2020).

Large Carrier Cargo Operations. Large carrier cargo operations are one of the significant steps toward achieving AAM. These cargo operations will either be piloted externally or have optional controls, allowing unmanned cargo transport in all environments. This capability will require revolutionary new aircraft that can safely maneuver both rural and urban environments with a high level of autonomy (FAA, 2020).

Passenger Transport Operations. When passenger transport operations are fully functional, then integration has been achieved. The primary vehicles for this unmanned passenger transport will likely be electrically powered, vertical takeoff and landing (VTOL) vehicles. This will allow them to be maneuvered within the confines of an urban environment. These aircraft will need to have complex automation to ensure safety (FAA, 2020).

Key Research Areas

Previously known as UAS research domains, the key research areas are a few areas that the FAA has identified as needing further research and development to help accomplish the operational capabilities (FAA, 2022). The following is a description of each of these areas and how they relate to the operational capabilities.

Remote Identification (Remote ID). One significant step forward that is already coming to fruition is the requirement for Remote ID (FAA, 2022). Remote ID is vital for the integration of UAS and supports all seven capabilities. Remote ID allows authorities to identify and track UAS to ensure compliance with laws and regulations. The FAA refers to the Remote ID as a kind of license plate. Remote ID is the precursor for any capability that requires a UAS to go beyond its visual line of sight (BVLOS). This technology can help authorities monitor and enforce no-fly zones, maintain the separation of UAS from other aircraft, and investigate incidents or accidents involving UAS. It can also help authorities identify a UAS operator flying in a prohibited area or over private property. In addition, Remote ID can help to prevent the malicious use of UAS, such as by terrorists or other criminals, by allowing authorities to identify and track the UAS and its operator (FAA, 2022).

After September 23 of 2023, Remote ID will be required for all UAS that weigh more than 250 grams (FAA, 2022). This is a massive step towards the integration of UAS because it will significantly increase the ability of law enforcement to enforce part 107 regulations. Remote ID will greatly help in urban environments by allowing some form of ATC influence. Regulations like this one may upset certain UAS pilots because it forces them to reveal their location and possibly purchase a remote ID transmitter (Moss, 2020). Advancements like this, however, are what make integration a possibility. With the current level of technology, most UAS cannot operate safely when BVLOS or in urban environments. This has led to the FAA heavily restricting this operational style for now.

The proposal for this system was originally met with strong opposition from some drone pilots (FAA, 2020). Companies are currently creating drones that will be compatible with Remote ID, but if a drone is not compliant, operators will be required to purchase a separate Remote ID module that they can attach to their UAS. Operators will be required to link their Remote ID to their registration which will allow law enforcement to see the location of the drone and the station from which it is being operated. There will be certain pre-established locations where it will be legal to fly without Remote ID as long as the operator requests permission and follows any applicable regulations. The FAA announced this deadline well in advance to give operators time to comply.

Detect-and-Avoid. One report from NASA explains that detect and avoid technology (DAA) is “A unique collision avoidance algorithm and sophisticated display options that exceeds FAA requirements for unmanned aerial systems (UAS) to fly in National Air Space (NAS)”

(Artega, 2017, para. 1). DAA technology is vital to the integration of UAS because BVLOS operations will not be possible without this level of automation (FAA, 2022).

Since DAA technology is still rapidly developing, many different forms of implementation are being created. One of the most popular approaches is to use onboard sensors, such as radar, LiDAR, or electro-optical cameras, to detect other aircraft or obstacles in the UAS's environment. The computers onboard the UAS can calculate the movement of these other obstacles or aircraft and predict where they may be in the future. This information is then used to generate a collision avoidance plan, which the UAS executes to avoid the detected threat. Another approach is to use communication-based DAA. This type of DAA relies on UAS to communicate with each other through their own radio wavelength, which makes it possible for them to detect each other before they are close enough to make visual contact with one another. Both of these systems for DAA technology have been experimented with successfully and could be a major step toward full integration if they are widely implemented (Neuhaus & Lu, 2018). There is still a need for further research and development in this area to ensure that DAA systems are reliable and can handle a wide range of potential threats. Research and experiments to further improve upon technologies like DAA technology are vital for further integration ever to occur.

Command and Control (C2). Command and Control (C2) is the method through which a UAS is manipulated and controlled by the pilot (Amorim et al., 2019). The communications for command and control can be radio transmitted, transmitted through a tether, or entirely autonomous with no potential for human input after takeoff. For full integration to occur, completely reliable methods of C2 need to be more accessible to the public. BVLOS and other complex operations become much more dangerous and unreliable if these C2 methods are unreliable. Another aspect of C2 development is the need for these communications to be secure. If these control channels are unstable, it could lead to the use of large numbers of hacked drones for malicious purposes (Yaacoub et al., 2020).

Human Factors. Human factors is a major topic in any form of aviation, and this is true for “unmanned” systems as well. Human factors involve medical factors, human error, psychological factors, and other factors relating to the link between a pilot and their aircraft (Mouloua et al., 2019). Understanding these factors better will allow for more complex operations and help determine what level of human intervention should be involved in further operational capabilities such as package delivery and scheduled operations.

Forecasting. The task of forecasting future development in this industry is a difficult one (Wargo et al., 2016). Although the FAA is working with many major industry partners to work toward future development, the rapid pace of innovation within the UAS industry makes it difficult to forecast the future of growth. The UAS operational capabilities are a way for the FAA to help guide future development towards these specific goals, allowing for better forecasting.

Forecasting also includes the need for future legislation. The FAA is in a difficult place when it comes to UAS regulations. This field needs further regulation and technological development to reach its full potential (FAA, 2022). Research shows that some of the regulations surrounding this industry are creating barriers to its development. One article explains, “In addition, the growing regulatory requirements create a big challenge for UAV development projects” (Idries et al., 2015, para. 10). This shows the delicate balance that must occur with regulation. If the industry is not regulated, safety hazards will lead to a regression of the industry, but if the industry is overregulated, it will be impossible for it to grow.

UAS Functional Areas

To help ensure that each of these operational capabilities is fully achieved, the FAA has developed UAS functional areas (FAA, 2020). These areas act as a sort of checklist that can be used with each operational capability to ensure that they have been fully accomplished or check the current state of development. Figure three shows some of these operational capabilities and how they build upon each other, address challenges, and work toward integration. The following is a brief description of each functional area (FAA, 2020).

Policy

For each of the operational capabilities to be fulfilled, there are pre-rulemaking activities that must be performed to help inform FAA decision-making. Then, policies and regulations can be created to enable each capability.

Security

One large area of concern within the most recent FAA roadmap toward UAS integration was the topic of UAS pilots with malicious intent (FAA, 2022). Implementing remote ID will be helpful in identifying those not following airspace boundaries or other regulations. Simply identifying threats is not enough to ensure safety. The FAA has partnered with several departments within the government, including the department of justice, department of homeland security, and department of the interior, to develop methods to handle potentially dangerous UAS. These methods are called counter-UAS and are a vital factor relating to the safety of UAS integration (FAA, 2022).

Air Traffic Management

Air traffic management is a significant topic in both manned and unmanned aviation. With each capability, there will be more traffic to manage (FAA, 2020). This prospect becomes even more complicated with integrated operations between manned and unmanned aircraft.

Airspace

The airspace required for each operational capability is closely related to air traffic management. With each capability, it must be designated which aircraft are allowed to operate in each airspace.

Capabilities and Systems

For each operational capability, the capabilities and systems to properly support them must be fully developed. These capabilities include some of the key research areas such as command and control and detect and avoid technology.

Aircraft Certification

Aircraft certification is a major step toward each operational capability. One article explains, “With the low costs of most micro-drones come low standards of hardware and software quality assurance” (Clarke & Moses, 2014, para. 14). People often purchase low-quality drones, which are much less capable of avoiding collisions and accidents. Aircraft certification for specific UAS operations would help minimize the hazards that can come with cheap drones.

Procedures

Every operational capability requires the development of specific procedures. These procedures may be for operators, controllers, manufacturers, maintainers, or anyone else involved with the operation.

Standards

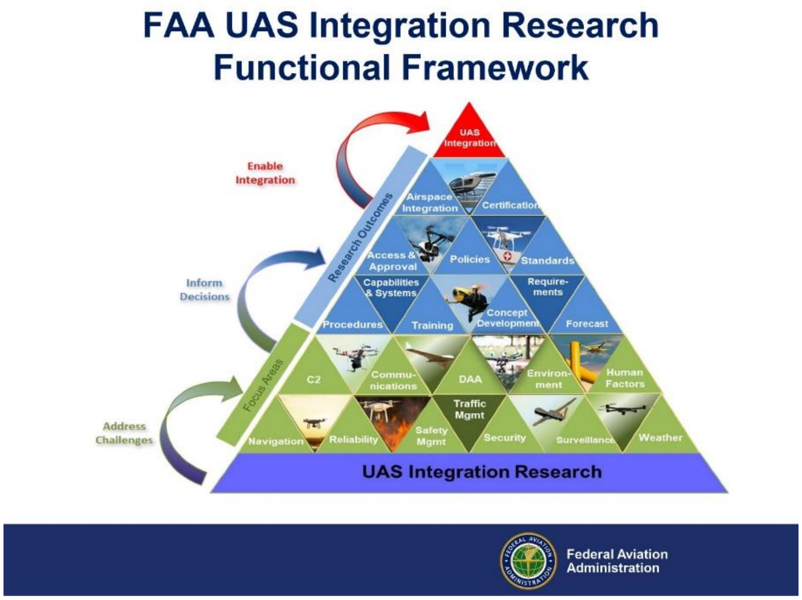
The development of standards is a broad topic, but it can relate to pilot certification, vehicle parameters, and other systems related to flight. Standards are vital because they establish minimums and practices that make the industry more uniform. With each operational capability, it is key to establish standards to ensure safety.

Training

Another major issue within the field of UAS is the large number of pilots breaking regulations (FAA, 2022). Since SUAS are relatively cheap and easily accessible, it is easy for someone with no knowledge of the regulations surrounding this technology to purchase a UAS and begin flying. This leads to users continually breaking airspace regulations, exceeding maximum altitudes, operating over uninvolved parties, performing commercial operations without a license, etc. Not only can these pilots endanger other aircraft and people on the ground, but they can negatively impact the perception that the public has of this industry. Further training would prevent many of these illegal pilots simply because they would know the regulations. It is vital that with each operational capability, an adequate amount of training is required for the operators performing that capability.

Figure 3

(FAA, 2020, p. 25)



Major Developments Towards Integration

Part 107

One of the early wins for the FAA is the creation of the Part 107 rule, which informs the Operations Over People capability as well as subsequent integration capabilities. This set of regulations acts as a guideline for operators which shows them what operations are legal. If an operator wishes to perform an operation that lies outside of the bounds of Part 107, they must submit a certificate of waiver or authorization to request permission for that operation (14 CFR Part 107, 2021).

Low Altitude Authorization and Notification Capability (LAANC)

LAANC has been an essential piece of the integration of UAS into the NAS (FAA, 2022). LAANC is one of the first significant steps toward automated UTM. With LAANC, flying a UAS in controlled airspace changed from a long process that required waivers and additional workload for ATC to an automated process that can be approved almost instantly. LAANC was built on the foundation provided by UAS facility maps (UASFMs). These maps are tailored to individually controlled airspaces to show pilots what altitudes and locations are available for LAANC auto-approval. This is a significant step towards several of the operational capabilities that have been mentioned because it limits the time and effort required to fly within controlled airspace.

One of the main reasons that LAANC is such an impactful development is its ability to assist with each of the operational capabilities. Other than operations over people, each of the UAS operational capabilities involves some form of flight into controlled airspaces. LAANC has opened the door for quick and efficient flights into these airspaces without days of paperwork and requesting permission.

Certificates of Waiver or Authorization (COA)

If a UAS pilot needs to request permission for an operation that falls outside of current regulations, they may submit a COA (FAA, 2019). In the past, these waivers were very unlikely to be approved and took much longer to be fulfilled (FAA, 2022). With the new online system, these waivers are usually met with a response within 60 days (FAA, 2022). In the future, the FAA wants to move away from needing waivers for more complex operations. It is still a significant advancement that waivers have become more streamlined and effective. These COAs have allowed for far more operations over people and complex operations, so these have already helped the UAS operational capabilities be achieved.

The State of Unmanned Traffic Management (UTM)

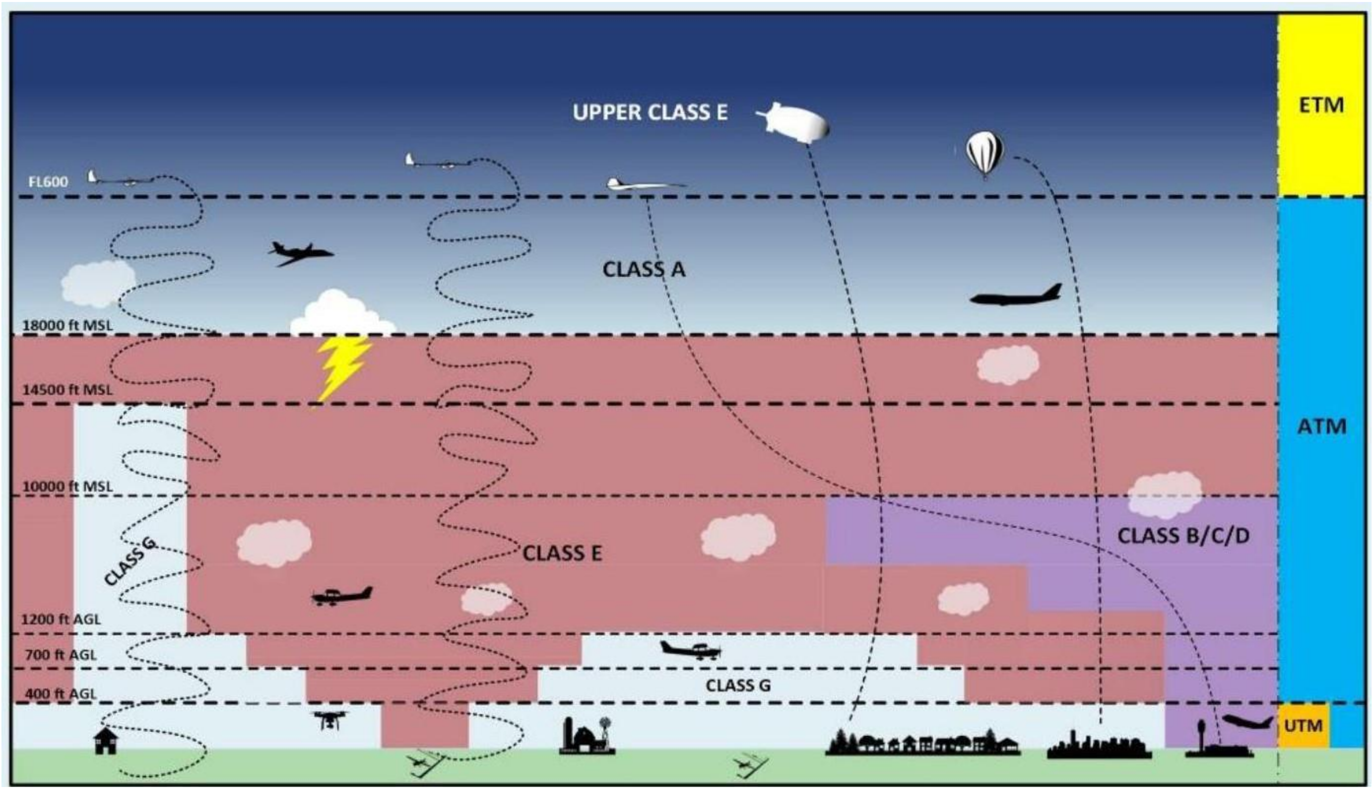
UTM is a broad topic, and it comes with many separate issues that must be addressed, such as command and control technology, regulatory issues, and many more (FAA, 2022). UTM primarily focuses on managing small UAS below 400 feet above ground level. Some significant steps towards accomplishing an all-encompassing system of UTM have already happened, including LAANC and Remote ID, but this system does not need to be developed by itself. Advancements in technology within other industry sectors can be applied to UTM, helping it advance and prepare the industry for full integration.

The FAA breaks airspace management down into categories: UTM, which only encompasses unmanned traffic under 400 feet, air traffic management (ATM) which includes all traffic from 400 feet above ground level to 60,000 feet above sea level, urban air mobility (UAM) airspace which revolves around the potential for UAM and expands through both the UTM atmosphere and the ATM atmosphere, and upper-class E air traffic management which includes aircraft above 60,000 feet above sea level (See figure Four). Both ATM and ETM include both manned and unmanned vehicles within their confines. ATM can be broken down further into two categories: mixed traffic consisting of instrument flight rules (IFR) traffic and visual flight rules (VFR) traffic below 18,000 feet above sea level and non-mixed traffic consisting of IFR traffic only above 18,000 feet above sea level. For UAS to be successfully integrated into these airspaces, it is vital for the operational capabilities to be met.

One major difference between UTM and typical air traffic control is that a large amount of interaction happens between the operator and a UAS Service Supplier (USS) rather than directly between the operator and an FAA control tower. USSs are contractors for the FAA that are charged with being responsible for certain airspace or function, and they work directly with operators to ensure safety and compliance. The FAA still maintains control over the airspace, but these suppliers help take the workload off the FAA’s ATC infrastructure.

Figure 4

(NASA, 2021, p. 20)



FAA Research Partners and Programs

The path toward full integration requires extensive research, investment, collaboration, and effort. The FAA has partnered with many different groups, departments, and organizations to help accomplish integration as efficiently as possible. (FAA, 2022).

UAS Executive Committee (EXCOM)

The EXCOM consists of representatives from the FAA, Department of Defense (DoD), Department of Homeland Security (DHS), National Aeronautics and Space Administration (NASA), Department of Interior (DOI), Department of Justice (DOJ), Department of Commerce (DOC), and the Department of Energy (DOE) (FAA, 2016). This committee is used to share information between these departments regarding the developments surrounding UAS and their integration. This allows these organizations to work together rather than working separately on the same issues.

UAS Center of Excellence (ASSURE)

ASSURE is an alliance consisting of 26 universities. This alliance aims to research and develop technology that can help integrate and expand UAS (Assure, 2022). Each university within this alliance is researching a different area relating to UAS. Some of the critical areas that they are focusing on include UAS noise reduction, DAA technology, UAS pilot training, UTM, low altitude safety, etc.

Industry

The FAA began the Advanced Aviation Advisory Committee (AAAC) to provide a place for essential industry partners to provide feedback and suggestions to the FAA as integration unfolds (FAA, 2023). This committee consists of high-ranking executives from the UPS, National Air Traffic Controllers Association, several state departments of transportation, several fire departments, several universities, Amazon Prime Air, Skydio, Boeing, Zipline, and many others. These meetings are open to the public and are an example of the FAA working with major partners within the industry to make full integration possible.

UAS Test Sites

The FAA has established 7 UAS test sites in the United States (FAA, 2022). The UAS testing sites play major roles in every UAS-related program and research project the FAA leads. These sites were selected after a competitive process, and they are used to research and experiment with more complex UAS operations. Some of the areas they are researching include the following: DAA, command and control (C2), BVLOS operations, UTM, c-UAS, and urban air mobility (UAM). These sites work directly with the FAA to develop the technology that is needed to advance integration.

Standard Groups

The FAA is working with several standards groups such as the Radio Technical Commission for Aeronautics (RTCA), American Society for Testing and Materials (ASTM), Society of Automotive Engineers (SAE), American National Standards Institute (ANSI), Institute of Electrical and Electronics Engineers (IEE), and the International Telecommunication Union (ITU) (FAA, 2022). These groups can help the FAA establish standards for integration and R&D within this field.

International Partners

Through international partnerships with several nations and organizations like the International Civil Aviation Organization (ICAO), The North Atlantic Treaty Organization (NATO), and the European Union Aviation Safety Agency (EASA), the FAA plans on being a world leader towards UAS integration and development (FAA, 2022). These international partnerships will also allow for more standardization which will help as UAS technology continues to develop.

Research Organizations

The FAA also partners with several other research organizations to help advance the research within this industry (FAA, 2022). Organizations like the National Academy of Sciences, The National Science Foundation Center for UAS, The National Institute of Standards and Technology, and several others work with the FAA to research pertinent issues within the field.

UAS Pilot Programs

The FAA has created two UAS pilot programs that involve partnering with government agencies, industry partners, and academic institutions to test advanced UAS operations.

UAS Integration Pilot Program (IPP). The IPP began in 2017 and was a collaboration between the FAA and state, local, and tribal governments, along with private entities, to test and evaluate the integration of UAS into the NAS (FAA, 2022). This program helped the FAA create new regulations while evaluating what level of integration could be safely legalized. This program was broken down into three success areas upon completion.

Safely Integrate UAS into the NAS. The first goal of this program was to improve the level of integration that UAS have in the NAS while increasing the safety of these operations. Within the program, over 21,000 flight operations were held, and the first two air carrier certificates for UAS cargo delivery operators were approved. The program also worked towards BVLOS operations. It was shown that open communication with the FAA and specific requests greatly increase the likelihood of waivers being approved. This program also showed that parachute systems mounted on UAS could minimize risks to persons on the ground during UAS operations. These findings could help the industry move towards legal operations over uninvolved parties.

Societal and Community Considerations. Throughout the process of trying to increase the level of integration, this program considered the impact that this integration could have on the public. To increase the societal benefit of this integration, the IPP improved access to medical supplies and goods and services, improved employee safety and security, improved support for disaster response, and focused on improving public engagement on UAS issues. Surveys taken in this process showed that the public approved of UAS when they were used for emergency response, inspections, medical delivery, and emergency response. The public was concerned about the privacy, safety, and security of these systems. Early community engagement was vital to increasing public acceptance of these activities (FAA, 2022).

Inform FAA Policy and Decision Making. Another major goal of this program was to provide the FAA with recommendations for regulations that will allow for safe yet effective integration. This program progressed type certification for SUAS, gathered data to inform policymaking about UAS type certification durability, established UAS C2 link testing metrics, conducted UAS noise testing, supported the development of UAS safety risk management policies, and gathered data to engage communities properly. This amount of technological development and experimental data allowed for many recommendations to the FAA. Firstly, it showed that with the increasing demand for BVLOS operations, continuing the current system of requiring waivers through part 107 may not be scalable. It was also shown that obtaining the proper certificates to pursue package delivery is a highly complex process that needs to be made clearer to make integration feasible.

UTM Pilot Program (UPP). The FAA Extension, Safety, and Security act of 2016 established the UPP to define the necessary capabilities to support UTM operations (FAA, 2022).

Phase One. Phase One of the UPP utilized three UAS Test Sights: Nevada Institute for Autonomous Systems, Northern Plains UAS Test Site, and Virginia Tech, Mid Atlantic Aviation Partnership. Phase one demonstrated the use of the exchange of flight intent among operators, the generation of notifications to UAS operators regarding air and ground activities, and the ability to share these notifications with stakeholders such as other UAS service suppliers and the Flight Information Management System (FIMS) (FAA, 2022).

Phase Two. Phase two of the UPP focused heavily on Remote ID technologies. The UAS Test Sites that participated in this phase were Virginia Tech, Mid Atlantic Aviation Partnership, and the Griffiss International Airport. This phase was completed in the fall of 2020 and made great advancements in the deployment of and use of Remote ID technology, showcasing the amazing potential that this technology has to improve integration.

How Do These Programs Work Together? The FAA (2022) states the following:

> IPP's purpose was to advance the UAS industry by informing regulations that permit more complex, demand-driven UAS operations and push the boundaries of UAS use. In support of future UAS operations, UPP's purpose is to pilot a UTM ecosystem built on architectural infrastructure and data services that allow USSs, operators, and government organizations to communicate and share information that will move toward the FAA's future implementation of UTM. (para.15)

This explains the purposes of each of these programs and how they are working in conjunction to increase the rate of integration.

Important Documents Provided by the FAA

As integration has evolved, the FAA has published many important documents that relate to this topic. These documents are the ultimate governing sources on what is happening with the topic of integration, and each serves its own purpose. Each of these documents is easily accessible on the FAA’s website.

UAS UTM Concept of Operations

The UTM Concept of Operations lays out in detail the steps that are being taken toward developing a full system for unmanned traffic management (FAA, 2020). This document discusses future growth, different possible operations, research areas that must be addressed, and several other key areas that are vital when discussing the topic of UTM. As the FAA's official concept of operations, this should be seen as the definitive source when discussing UTM.

IPP Final Report

The IPP final report relays the goals and results of the IPP. This document shows which research centers performed research into each specific area and relays the results that they found (FAA, 2022). The research performed within the IPP has provided valuable data and feedback that has helped with further integration.

UPP Summary Report

The UPP summary report relays the goals and results of the UPP (FAA, 2022). This document breaks down the phases of this project and explains how each one contributed towards further integration. This program helped lay the foundation for certain complex operations such as BVLOS operations and flights over people.

Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) roadmap.

The UAS integration roadmap is possibly the most all-encompassing source of information on the topic of UAS integration (FAA, 2020). This roadmap breaks down what has occurred to support integration, what barriers are preventing integration, and what is being done to overcome these barriers. This roadmap provides guidance to several other FAA resources and does an excellent job of discussing the plans to achieve integration.

AVS RE&D Portfolio

The AVS RE&D Portfolio lays out each of the operational capabilities and breaks them down into research questions that must be addressed to fulfill these capabilities (FAA, 2022).

This document goes on to break down some of the funding for this research while listing some of the important team members on the board that created this plan. This document is useful if an operator needs a more detailed breakdown of the operational capabilities.

Additional Issues to Consider

The FAA mentions several other issues that must be addressed when considering the integration of UAS into the NAS (FAA, 2020). These may not be key research areas on their own, but they are worth considering.

Public Perception

The public perception of this industry is a significant factor in its possible expansion and development (FAA, 2022). Without public approval, it is difficult to obtain funding or pass legislation that helps advance the integration of UAS. The FAA has made a large push toward educating the public and the drone community. Members of the general public that are not involved with the field of UAS generally learn about UAS through the media. This often leads to them distrusting and misunderstanding UAS (Aydin, 2019).

It has been proven that the public perception of drones can be increased when the functions of certain UAS are explained to the public. One article states, “When used for helpful and noninvasive applications, the public’s perception of RPAS (remotely piloted aircraft systems) is overly positive. This was especially significant for the use of RPAS in firefighting situations, where all responses were non-negative” (Graham et al., 2019, p. 13). This shows that it is possible for the public perception of this topic to be swayed for the positive, which will be necessary to continue developing further integration.

Environmental

One of the most significant issues facing the integration of UAS into the NAS is the amount of noise they create (FAA, 2022). This noise will be a more significant issue in urban environments, but it will be a factor anywhere UAS are integrated. Since most designs for package delivery and AAM are VTOL aircraft, they produce high amounts of noise pollution. There are already many issues with noise pollution around airports, mainly the public's complaints about this pollution (Homola et al., 2019). The FAA is working on designs and plans to reduce the noise pollution that a large amount of unmanned traffic would cause, but it is impossible to eliminate the noise entirely (FAA, 2022). Noise pollution is not the only aspect of this equation. Even if UAS were made silent, they are still visible. There are those that are uncomfortable with the prospect of having UAS involvement in their daily life (Miller, 2016), so seeing this high amount of potential traffic may make them uncomfortable. This is an aspect of public perception, but the noise and sight of this many UAS operating in low airspaces is an environmental aspect that must be considered.

Conclusion

The path to full UAS integration is certainly a long, labor-filled one. It is clear that full integration into the NAS could benefit society in many ways if it is done properly. If this process is rushed or performed in an unsafe manner, it could set the industry back for years. The FAA is working heavily with a large number of partners to research and develop the means to manage the massive number of UAS that already exist and those that will continue to come with further integration. Some of the barriers to UAS integration, such as noise pollution, do not have a definite solution currently, but there is research being done to overcome each barrier. In recent years, there have been large strides towards full integration, such as LAANC and Remote ID, and these have greatly benefited the industry as a whole. As UAS integration continues to evolve, the importance of the public perception of this industry cannot be underestimated. Without proper communication with the public, it would be easy for their disapproval to greatly hinder this integration. In conclusion, UAS are a major tool that have the potential to change the world for the better, but to accomplish this change; the industry must take its time and find the safest, most efficient way to break into new areas.

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