Regulatory challenges affecting the adoption of uncrewed aircraft systems in agriculture

by

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B.S., Kansas State University, 2017

A REPORT

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Aviation
College of Technology and Aviation

KANSAS STATE UNIVERSITY
Salina, Kansas

2025

Approved by:
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Abstract

In August of 2016, the Federal Aviation Administration (FAA) released regulations for Small Uncrewed Aircraft Systems (sUAS), or drones, operating in a commercial manner. These regulations (Part 107) allowed for the widespread adoption of drones weighing less than 55 pounds for countless industries. One use that many are still hopeful will adopt drone technology is agriculture, specifically for crop spraying. However, since the majority of aerial applicating drones fall outside of the weight restriction of Part 107, this particular use hasn't quite taken off as expected because of the regulatory framework for drones weighing 55 pounds or larger. This paper focuses on the processes that the FAA took for developing and releasing Part 107 and outlines what the future could look like for commercial drones that fall outside of that regulatory environment, including drones used for aerial applicating. Additionally, this paper will discuss general views of farmers in Kansas on the use of drone technology in agriculture and how that affects adoption rate. Finally, this paper will consider the types of drones available on the commercial market today as well as how other countries are using them for agricultural purposes.

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Introduction

The Federal Aviation Administration (FAA) released regulations for Small Uncrewed Aircraft Systems (sUAS), or drones, operating in a commercial manner in 2016. These regulations (Part 107) allowed for the widespread adoption of drones for industries like oil and gas, real estate, public safety, transportation, cinematography, inspections, and many others. Not only are drones being used for a wide number of industries, but they are also being used for a variety of uses within each industry. For example, within public safety, UAS can be used for search and rescue, accident scene reconstruction, first responder (first to arrive on the scene), delivering medical supplies, and clearing buildings after a natural disaster. For inspections, drones can carry a multitude of sensors such as thermal, multispectral, RGB, and LiDAR.

One industry that many are still hopeful will adopt drone technology is agriculture, specifically for crop spraying. However, due to the regulatory complications of spraying hazardous chemicals from a drone and considering that most spraying drones fall outside of the weight requirements of Part 107 [1)], this particular use hasn't quite taken off as much as was hoped for by the agricultural industry. To help determine the outlook of aerial application by drone, specifically for drones that fall outside the scope of Part 107, this paper first reviews the process the FAA used when developing the Part 107 regulations. Then, the current regulatory framework for aircraft that fall outside of Part 107 (larger than small UAS) is reviewed for where it stands today as compared to part 107. Finally, the paper will look discuss opportunities for the agriculture industry to use drones, including what types of UAS are being used as well as how prevalent their use is in other countries outside of the US [2)]. By comparing the current state of regulations for larger than small UAS with Part 107, a timeline could be developed for at-scale adoption of larger than small UAS for aerial applicating purposes. Additionally, businesses could make educated decisions for when to begin the adoption process for these types of drones, posturing themselves well for the future precision agriculture technology (PAT).

Review of Literature

The purpose of this literature review is to discuss any known papers that cover the FAA's regulatory development process, specifically for regulations that govern small UAS, or UAS that weigh less than 55 pounds. While few papers have been published that cover this subject, this section will mainly aim to discuss the process as published and discussed by the FAA.

Current Findings

At the time of this paper, few research papers were found that outline the FAA's rulemaking process as it pertains to UAS in the last 10 years. One paper entitled "Uncharted Territory: The FAA and the Regulation of Privacy via Rulemaking for Domestic Drones", written by Melissa Barbee, describes some of the processes the FAA takes to publish new regulations in the United States (Barbee, 2014). The FAA's number one priority is safety and all regulations and advisories stem from this mission [3]. As an arm of the Department of Transportation, the FAA is tasked by the United States Congress with overseeing all civil aviation in the United States, and internal initiatives change over time due to oversight by Congress. Barbee discusses the FAA's responsibility to integrate UAS into the national airspace system (NAS) because of the FAA's Modernization and Reform Act (FRMA). This FRMA (P.L. 112-95) was released in 2012 and was the initial step in a long road to regulating drones in the US.

Barbee's paper discusses how the FRMA was responsible for developing a department within the FAA that is still in operation today: The Unmanned Aircraft Systems Integration Office (AUS). AUS was charged with leading the effort to integrate UAS and is organized into four separate divisions- the Business and Planning Division, International Division, UAS Research, Engineering, and Analysis Division, and the Safety and Integration Division. These four divisions are tied together through the Executive Office, which is the main hub for all communication through the FAA regarding UAS [4]. Barbee then transitions from the discussion of the FAA rulemaking processes to the FAA's stance on privacy concerns with drones.

While there have been few papers that discuss the FAA's rulemaking process in depth, the DOT branch publishes a wide range of documentation that outlines its process. As discussed above, rulemaking generally comes because of legislative directives, but there are several other factors that may cause the FAA to create new rules. For example-

- Recommendations from accident investigations
- New aviation/avionics technologies
- Petitions for rulemaking and exemptions
- Committee recommendations

While there may be different drivers for rulemaking, the FAA has a standardized process for implementing rules at the Federal level, rather than publishing them immediately. In fact, once new regulatory ideas are proposed, it may take years before they are finally published as part of the Code of Federal Regulations. Figure 1 below represents the published procedure used once new regulatory areas are established and include an average timeline of each stage. This figure is discussed in depth below.

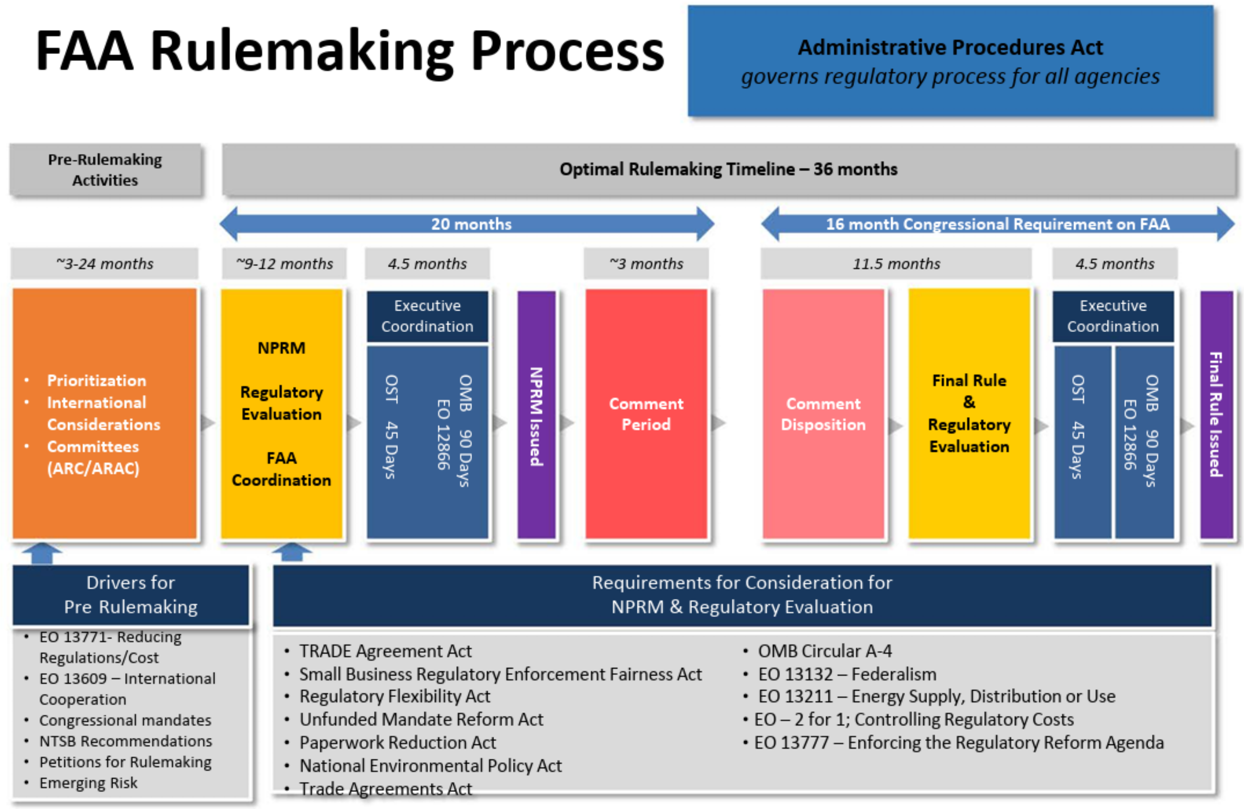

Figure 1. FAA Rulemaking Process

This photo, derived from the FAA's publications, outlines the steps that are taken prior to publishing new regulations, and is the same process that was used to develop Part 107. Once new regulatory ideas have been selected, the next step is for priorities to be set. Often, Congress sets the timeline for the FAA to have regulations in place. For example, the FRMA in 2012 outlined a timeline for the FAA to set up six UAS test sites around the country. As a result, the FAA had to prioritize their taskings accordingly. In addition to the prioritization piece, Aviation Rulemaking Committees (ARC) and Aviation Rulemaking Advisory Committees (ARAC) may be formed to determine the best path forward for a proposed or requested regulation. These committees have slight variances but ultimately provide information, advice, and recommendations to the FAA on certain topics. It is common for these committees to be widely represented, consisting of individuals from public interest groups, foreign civil authorities, aviation associations, the aviation industry, and advocacy groups [5]. While ARCs tend to be shorter in duration, ARACs may take longer to provide the necessary reports to the FAA. Therefore, this stage of the process can last anywhere from 3-24 months.

The next internal stage is the formulation of a Notice of Proposed Rulemaking (NPRM) and Regulatory Impact Assessment (RIA). The NPRM is a draft rule for the eventual regulation. While the NPRM is reviewed by many individuals and divisions, the main rulemaking team is comprised of a technical expert, a rulemaking analyst, an attorney, and an economist. As the NPRM is developed, these individuals must ensure compliance with a few notices, such as the Paperwork Reduction Act, Regulatory Flexibility Act, and the Trade Agreements Act among others. Along with the NPRM, an RIA is also developed which provides an analysis of the benefits and costs of the proposed rule. Once these documents have been circulated internally and reviewed at the executive level, the respective NPRM is issued for public comment. The comment period allows the public to comment on any items of concern, things they would like changed or removed, and for new thoughts to be brought up to the FAA. This takes the review process from just a few dozen people to sometimes tens of thousands of people [18].

While the review period may take as little as 30 days, there are instances where the FAA allows comments to be posted for up to 180 days. Upon closing of comments, the FAA must then compound all comments, which can be a significant undertaking depending on the NPRM. As part of this sequence, comments are taken into consideration but are not the final step in deciding whether to continue with a final version of the regulation. Supplemental NPRMs could be published if the FAA feels that, because of the comments received, the final rule should be changed significantly. Once the comments have been sifted through and responses have been formulated or discussed, the FAA moves forward with a final RIA in addition to the promulgation of the final rule. During this phase, a new RIA is needed after any changes that may have been made due to the commenting phase or any concerns raised during that same phase. The rulemaking team completes the final rule and then hands it off for executive review. Finally, the rule can be issued as final to the public, and the process is complete. This same process is how Part 107 was developed and implemented in August of 2016, and it is continuing to be used for forthcoming regulations for small UAS, including Part 108 for beyond-visual line-of-sight flight operations. However, not all UAS have Federal regulations that have been developed using this process, including UAS weighing 55 pounds or more.

Alternatives to Regulatory Rulemaking for the FAA

Reauthorization Acts for the FAA, such as the one in 2012, happen every several years. After 2012, the latest one was released in 2018 [18]. Section 44807, entitled, "Special Authority for Certain Unmanned Aircraft Systems" was included in the FAA's Reauthorization Act of 2018 and pertains to civil UAS that do not fall under Part 107. This includes drones that weigh 55 pounds or more. As was mentioned above, one of the factors that push the FAA to new rulemaking is mandates from Congress. Verbiage within the Reauthorization Acts determines whether it should be a law, a report, a process, or a similar type of commitment. When Congress directed the FAA to create civil regulations for small UAS, it was a result of the popularity of such drones and their benefits for a wide range of industries. Today, small UAS are still the primary drone type on the market, and drones 55 pounds and larger (larger-than-small) have not required the level of rulemaking we saw in 2016. As a result, Congress has not directed the FAA to create regulations for these larger-than-small UAS. However, they have directed the FAA to create avenues for governing these drones, namely by Section 44807. Section 44807 operations are referred to as “Section 44807 Exemption”, denoting that the UAS operator is requesting relief from the requirements of Part 107.

While UAS operators are certified under Part 107 most commonly by passing a written exam at an FAA Knowledge Testing Center, Section 44807 of the FAA’s Reauthorization Act of 2018 requires operators to go through a different process. First, an applicant must develop or provide the following documents to request an exemption from Part 107:

- Concept of Operations
- Operations Manual
- Emergency Procedures
- Checklists
- Maintenance Manual
- Training Program
- Flight History
- Safety Risk Analysis

Once these documents [18] have been combined, the applicant should also refer to 14 CFR § 11.81, “What Information Must I Include in my Petition for an Exemption?”. Here, the FAA outlines what additional information should be included for the FAA to consider the individual’s request. Once all these documents have been developed and combined, they should be uploaded to the Federal Register Docket, which is public. Here, the public may choose to comment on the submission, like the NPRM process. The FAA typically leaves the comment section open to the public for around 30 days from the time of submission, wherein they will proceed to review the submission. The full review process, including the comment period, may take between 4-6 months before the FAA provides approval. Once the operator has received their approval, operations are conducted under a Certificate of Authorization (COA) which provides the limitations such as how far the drone may fly away from the pilot, how high the drone may fly, distance minimum from airports during flight, and several other limitations. There are two main types of COAs available- a Blanket COA and a Jurisdictional COA. Typically, a COA is valid for a minimum of one year, often being good for multiple years. Compared to Part 107, this path for operating under a Section 44807 Exemption is much more intensive and lengthier, and therefore often affects how companies or individuals use drones, and it is not unusual for these ones to find ways in which they can use small UAS to do jobs that larger-than-small UAS would be better suited for.

For example, an aerial applicating drone that is larger-than-small may be able to cover more acres in a day because of its carrying capacity for chemicals, but in order to fly within the Part 107 regulations, the company elects to fly a UAS that weighs less than 55 pounds and accept the fact that they will not be able to spray as many acres in a day. A more streamlined regulatory approach for aircraft weighing larger than small could improve efficiencies and have a large economic impact considering that many would likely take advantage of the standardized certification process.

Methodology

Considering where the FAA is at with the regulatory framework for larger-than-small UAS and that approvals are on a case-by-case basis, future directives from Reauthorization Acts could force them to create regulations for other weight classes of UAS. We have already seen Congress do something similar with the latest draft of the FAA's Reauthorization Act of 2023 [18]. In this draft, Congress requested that the FAA establish procedures, which could include rulemaking, for several things relating to UAS. Unfortunately, this latest draft extends the Section 44807 process, meaning that until at least 2028 when the Act expires, Congress will not have an influence on the development of new regulations for drones weighing 55 pounds or more. Regardless of the regulatory path an operator takes - Part 107 or Section 44807 Exemption – they must also apply to become certified as an agricultural aircraft operator under the FAA's Part 137 regulations. This process can take as long as 12 months to become fully certified and requires the applicant to conduct both a ground test and a flight test in front of FAA representatives. Finally, the individual must follow all state laws for the commercial application of chemicals which often includes an applicator's license. It is understandable why the adoption of this technology for aerial application has not occurred at a high rate in the United States.

In addition to the regulatory challenges that they face when adopting this technology, many farmers are simply unaware what the capabilities of the technology are. In a study completed in 2023 conducted by the author, Kansas farmers were surveyed over the following questions- 1) On average, much does your farm spend on herbicide/pesticide application per year? 2) What method(s) do you utilize for chemical application? 3) How likely would you be to adopt drone technology as a new method of application? 4) What barriers prevent you from adopting drone technology for aerial application? 5) What event(s) would be of interest to you in order to learn more about drone use as an application tool?

Results

Results were collected during a 4-week period and 27 participants completed a survey. While the results were anonymous, distribution of the survey was focused on farmers in Kansas. Of course, there is no way to determine if all 27 participants were located within the state. For each question, the results can be summarized as follows-

1) *On average, how much does your farm spend on herbicide/pesticide application per year?* 22% of the participants (6 responses) indicated they spend between $0-$9,999 per year. 48% (13 responses) indicated they spend between $10,000-$19,999 per year. 30% (8 responses) indicated they spend over $20,000 per year on herbicide/pesticide application.
2) *What method(s) do you utilize for chemical application? Select all that apply.* 69% of the participants (25 responses) selected ground rig. 31% (11 responses) selected aerial.
3) *How likely would you be to adopt drone technology as a new method of application? 1 being not at all likely, 5 being very likely.* 7.41% of the participants (2 responses) selected a 1, or not at all likely. 26% (7 responses) selected a 2. 30% (8 responses) selected a 3. 26% (7 responses) selected a 4. 11% (3 responses) selected a 5, or very likely.
4) *What barriers prevent you from adopting drone technology for aerial application? Select all that apply.* 33% of the responses reflected that participants were uncertain of the capabilities of UAS. 25% of the responses reflected that the financial requirement was a barrier. 19% of the responses were a result of participants hesitating to implement UAS as a precision agriculture tool. 6% of the responses were from participants who currently

utilize UAS for chemical application. The remaining 17% of responses were for “other” barriers.

5) *What event(s) would be of interest to you in order to learn more about drone use as an application tool? Select all that apply.* 33% of the responses indicated a field day / demonstration would be beneficial. 24% indicated an article series would be of interest. 21% selected a hands-on training course. 10% of responses were for a webinar-style event. The remaining 12% indicated they would not be interested in any event.

Discussion

The results from this survey provide evidence that farmers are thinking about utilizing the technology. Question 3 revealed that 67% indicated that they would consider using a drone for application purposes on their farm. However, only 6% of those polled were currently using drones for application purposes at the time of the survey. So, the question becomes- what is preventing the other 61% of participants from employing the technology? Question 4 also indicates that uncertainty of UAS capabilities, financial requirement to purchase a drone for applicating purposes, and hesitation to implement UAS as a precision agriculture tool all had an impact on those not operating them on their farms. Demonstrations, or field days, published how-to articles or reports, or hands-on training events could prove to be a solution for at least those who are unsure on the capabilities of UAS as well as those hesitant to implement them as precision agriculture tools. These events would be able to help educate those in the community about the capabilities and the workflow of integrating the technology on a farm. Hands-on training could be provided by Universities or other local entities so that those currently operating drones on their farm could refine their skills and add to their knowledge base. As time progresses, these events would hopefully lead to an increase in the number of farmers using the technology in Kansas and the United States in general.

Adoption of Drone Technology by Other Countries

While the United States has arguably the safest airspace in the world due to the FAA's oversight, other countries have not implemented such strict regulations and have therefore experienced many adopting drone technologies for agricultural purposes. Germany, for example, is seeing an increase in drone use on farms. In a study conducted by Marius Michels (et al., 2020), a survey of 167 German farmers was conducted to identify the intention to use drones for farm-specific tasks. The survey looked at the adoption of drones on farms based on farmers' view of UAS being useful, relevant, and easy to use, and their overall intention of using drones. The average age from the sample collected was 40 years old, with 65 of the 167 holding a university degree. 87% of the sample population were male participants, which is close to the German average for farmers of 90%. Therefore, the sample was not representative of German agriculture. Despite that, the bias of producing an online survey was welcomed by the research team as it was these individuals who were more likely to adopt drones as a PAT. In fact, 85% of those surveyed indicated that they intended to use drones on the farm in some capacity, while 88% viewed them as useful tools. Even with these numbers, the researchers found that only 22% of those surveyed used drones on their farms at the time of the study.

This was not the only study of the adoption of drones as PAT in other countries outside of the United States. A similar study was conducted by Attila Bai (et al., 2022) in Hungary using a logit-based approach, closely related to the study done in Germany. This survey, entitled "Examining the Adoption of Drones and Categorization of Precision Elements among Hungarian Precision Farmers Using a Trans-Theoretical Model" was comprised of a sample size of 200 people and the survey was done face-to-face. Given those differences, the study conducted by Bai et al. was modeled from the study done by Michels et al. Thus, the question design allows these two studies to be compared. In the second of these two studies, Bai found some interesting inclusions about Hungarian farmers First, the research team found that someone with higher education was 6.33 times more likely to use a drone than someone without higher education. Additionally, openness to adopting new drone technology decreases with age, which is a common theme for a multitude of technologies. The study conducted in Hungary found that 17% of those surveyed used drones on the farm at the current time, compared to the study in Germany where 22% currently operated drones on their farm [14]. Future studies that compare adoption rates of drones as PAT in the United States vs other countries with limited regulatory framework could be useful for economists and FAA executives to base rulemaking decisions off.

Current Drone Technology

The agriculture industry is one of tradition, and new techniques are slow to be adopted. The average age of farmers in the United States is 57.5 years old [20] and sticking with traditional methods is a natural thing for humans. Over the years however, the agricultural industry has seen many new technologies emerge to help increase efficiencies and improve yields. Improvements made in engines, the introduction of GPS, and satellite imagery are just a few of the ways farming has changed in the last few decades. UAS are no different, and over the last decade the technology onboard drones have rapidly advanced. This section aims to provide an overview of several different types of UAS available on the market.

Multi-rotors, like the one in Figure 2 below, are the most prevalent platforms on the market due to several factors. These aircraft fit the widest uses and, therefore, are produced more commonly than other types of systems. A multi-rotor has the capability of hovering for long periods of time and can access tight spaces. Camera options vary widely for a multi-rotor; RGB, infrared, multispectral, and lidar sensors are a few of the most common options integrated into the platforms. Many of these camera systems are installed on a motorized gimbal, which stabilizes the camera and reduces the effects of vibration or other movements of the drone. Flight endurance for a multi-rotor is limited due to the poor aerodynamic characteristics but often the capabilities for this type of system are worth the decreased time in the air when compared to other types. These platforms are the most prevalent systems on the market.

Figure 2. Multi-rotor UAS

Fixed-wing systems have become more common in agriculture with uses such as surveying, modeling, and crop assessment being most prevalent. Figure 3 shows a fixed-wing design, which resembles a conventional crewed aircraft. These systems have longer endurance when compared to a multi-rotor but lack the ability to hover in one location. A similar capability for a fixed-wing aircraft is called a “loiter”, which results in the aircraft circling/orbiting a small area. While these platforms can carry a wide range of cameras, the majority are not stabilized with a gimbal. Rather, these cameras are fixed in a nadir, or vertically downward, position.

Figure 3. Fixed-wing UAS

Hybrid VTOL systems have gained more popularity in several industries. However, agriculture continues to leverage multi-rotors and fixed-wing platforms more commonly. A hybrid VTOL UAS provides the operator with the takeoff and landing capabilities of a multi-rotor with the endurance and range of a fixed-wing UAS. Typically, these systems are large and while electric power is a common option, several options for liquid-fueled propulsion are available on the commercial market. Figure 4 represents a hybrid VTOL system. This aircraft has a max takeoff weight of 115 pounds and is liquid-fueled, providing nearly eight (8) hours of flight time.

Figure 4. Hybrid VTOL UAS

While there are several types of UAS, the most used platform for aerial applications is multi-rotors [15]. The capability of restricting flight to a tighter area than alternative platforms while still carrying adequate payload leads to this design being used more often than others. A typical multi-rotor flight for aerial application purposes goes as follows:

- Pre-flight inspection of the airframe and the operating area is completed.
- Substances, such as pesticides or fertilizer, are loaded.
- The flight plan is built and uploaded to the UAS for autonomous operations.
- The aircraft takes off and proceeds to the start of the flight route.
- UAS arrives at starting location and begins the aerial application.
- The aircraft completes the application and returns autonomously to the takeoff location.
- The drone lands and the process is repeated if necessary.

The capabilities of a multi-rotor make it ideal for performing aerial applications. In addition to the capabilities, there are many benefits of using these types of systems for applying chemicals to crops. According to the United States Environmental Protection Agency [16], application by UAS, specifically multi-rotor aircraft, results in a lower drift rate as the aircraft can fly closer to the canopy as compared to traditional means. Additionally, due to their size and lack of carrying a human onboard, these UAS can access tighter, more dangerous locations that other methods may be unable to access. Considering these aspects, it would be logical to conclude that UAS has been a popular choice for agricultural applications for many years. However, there have been a couple of factors preventing their implementation at scale.

Conclusion

In 2016, the FAA released regulations for UAS that opened the door for countless commercial drone uses. Some of the industries include uses within oil and gas, real estate, public safety, transportation, cinematography, inspections, surveying, wildlife management, insurance, and many others. Agriculture on the other hand has been slow to adopt drone technology, specifically for crop spraying [17]. The main cause for this is due to the regulatory barriers for drones 55 pounds and larger, which do not fall under Part 107. These aircraft are required to develop and submit to the FAA their Concept of Operations, Operations Manuals, Emergency Procedures, Checklists, Maintenance Manuals, Training Programs, Flight History, and Safety Risk Analysis.

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