UAVs in Agriculture: Perceptions, Prospects, and ”Probably Not”

Ganesh Kumar
University of Wisconsin-Madison
1210 W. Dayton St Madison, WI 53706
ganz@cs.wisc.edu

Ronak Mehta
University of Wisconsin-Madison
1210 W. Dayton St Madison, WI 53706
ronakrm@cs.wisc.edu

Margaret Pearce
University of Wisconsin-Madison
1210 W. Dayton St Madison, WI 53706
mlpearce@cs.wisc.edu

ABSTRACT
Unmanned Aerial Vehicles (UAVs) are changing workflows in a variety of different fields ranging from security to cinematography. In particular, agriculture is a field that is poised to strongly benefit from this technology. In this paper, we use an ethnographic field study to gauge the current perception of UAVs in the farming community. A Grounded Theory analysis of interviews with stakeholders was used to identify UAV trends, impressions, and interest. Our findings revealed relatively low familiarity with UAV technology among farmers but significant interest in future possibilities. Key concerns included the applicability of UAVs and the potential return on investment. Furthermore, government regulation of UAVs is a critical factor that is slowing adoption as legislative decisions wait to be made. Despite these concerns, stakeholders are curious to see the future value of utilizing this technology. These results contribute to our understanding of the role of UAVs in agricultural settings and inform future design implications.

Author Keywords
unmanned aerial vehicles; precision agriculture; ethnography

ACM Classification Keywords
K.4.3. Computer-supported collaborative work: Organizational Impacts

INTRODUCTION
The exponential growth of computing power and manufacturing processes has given rise to significant, radical changes in a large number of sectors. Jobs and tasks that previously required considerable manual human labor now are being completed by more efficient and cost effective machines. Many of these fields have not been technology-focused, historically, and so it becomes important to explore and ease the adoption of these technologies as much as possible.

UAVs are an example of a technology that is changing work patterns. In the past decade, UAVs have moved from their original military domain into a commercial one, finding applications in fields as diverse as filmmaking and package delivery[5][4]. In particular, agriculture is positioned to become the next commercial sector transformed by UAV use. However, the current adoption of UAVs in farming has been limited. In our background research investigation, we found a limited amount of literature detailing the nature and scope of UAV use in farming. It appeared that most prior work focused on the design of the technology for its own sake, and did not seem to address UAVs within their application context. Understanding context will have significant implications for future UAV design and development. The potential design implications and the growing demand for UAVs in agriculture provided motivation to study this context specifically.

In this paper, we detail an ethnographic study conducted on the current landscape of UAV adoption in agriculture. First, we outline the study's setting, consisting of interviews with relevant stakeholders in the industry. Then we describe our data collection process, in which responses were collected concerning a variety of topics we found pertinent through background research. Next, we present a Grounded Theory approach, and we identify core ideas linked to UAV perceptions and use. We conclude with an analysis of these theories, and their impact on future design.

BACKGROUND

Previous Work
Because of the young nature of the field, we found limited background literature on UAV perception[1][12]. Several papers talk significantly about the manufacturing and design of UAV technology[14], but none spoke directly to their use in agriculture.

An interesting related ethnography was conducted by William Odom in an Australian urban city, attempting to identify trends in community gardens related to remote sensing. They found ”resistance to technological interventions aimed at directly augmenting gardening practice”[11]. It is unclear if this phenomenon occurs in rural or large-scale settings as well. Our motivation for this study included exploring this same idea in the context of UAV use in agriculture as a whole.

Unmanned Aerial Vehicles
UAVs grew out of growing military use in the mid to late 20th century [8], and have since become more and more prevalent in the commercial and civil sectors. Because of the recent wide variety of UAV applications, terminology has become a recent hot topic for stakeholders[13][6]. In our study, we have taken the Federal Aviation Administration's (FAA) definition of an unmanned aerial system (UAS), stated as ”the unmanned aircraft (UA) and all of the associated support equipment, control station, data links, telemetry, communications

and navigation equipment, etc., necessary to operate the unmanned aircraft”[3]. Our use of the term UAV is synonymous with the term UAS, and was chosen for its familiarity and connotation.

UAV Legislation

As a recent technology trend, acceptable use of UAVs remains controversial in the United States. At the time of writing, the existence and scope of laws concerning UAVs varied from state to state. In total, twenty states currently have laws on UAV usage with several more states considering new legislation[15].

Wisconsin’s 2013 Senate Bill 193 formally defines the term ”drone” and states that the flight of UAVs over land and water is legal with some caveats[10]. The bill establishes the operation of a weaponized drone as a Class H felony (excluding members of the U.S. armed forces or national guard acting in official capacity). Furthermore, usage is prohibited in places or locations where individuals are granted a reasonable expectation of privacy. This applies to law enforcement officials unless a search warrant has been obtained, with some exceptions.

At the federal level, the FAA created a roadmap for regulation in 2013. They set a goal to have in place ”FAA’s unique certification requirements for new and novel systems” by 2015. [2]. Currently, all business uses of UAVs require FAA approval. There are no requirements for recreational use at the federal level. Upcoming laws and guidelines will have a significant impact on the use of UAVs in all fields. In the context of agriculture, the size and location of a specific farming operation may determine the type of regulation applicable. A community garden with a small off-the-shelf UAV may not fall under the same category as a thousand acre farm with a specialized, large scale UAV. This is currently where some states have stepped in with minimal regulation, but everyone with a connection to the field is waiting on these FAA guidelines.

STUDY OUTLINE

To understand and appreciate how UAVs might be assimilated into the current farming practices, we conducted an ethnographic study with five stakeholders. In the following sections, we describe the sites that we visited, the stakeholders we talked with, the data collection methods we employed, and our analysis of the data.

Three of the stakeholders we interviewed for this study were small-medium scale farmers while the other two were large-scale farming services cooperatives. In general, a cooperative is a business owned and democratically controlled by the people who use its services and whose benefits are derived and distributed equitably on the basis of use[9]. The cooperatives we interviewed in the context of this study offer agricultural services and products. Additional offerings include consultations regarding business planning, record management, and technology usage.

Study Participants

Below are brief descriptions of the participants we recruited to participate in the study.

Cooperative 1 is an agricultural cooperative of about 250 employees that serves 2500 farms throughout Wisconsin and Michigan’s Upper Peninsula. It supplies agricultural products like seed, fertilizer, and chemicals to farmers and also provides a variety of agricultural services like nutrient management, precision farming and soil sampling. They cater to farms that cover, on average, 600 acres.

Cooperative 2 is an agricultural cooperative that employs about 500 employees and serves 4800 farms in the Southern Wisconsin and Northern Illinois area. They provide agronomy, energy, animal nutrition, grain and transportation products and services to their customers. The farms that the cooperative caters to are, on average, 1000 acres large.

Farmer 1 is a small-scale organic farmer who owns and runs a family-owned farm of around 20 acres. The farm grows 29 kinds of chilies, garlic, carrots and horseradish. They also sell processed products like jams, sauces and spreads. They also have a website and strong social media presence.

Farmer 2 is a garden director at a university-affiliated farm. The farm is small-scale, covering an area of about 2 acres. The farm grows mostly vegetables and gives away the produce for free. The farm is run entirely by students, volunteers, and university employees.

Farmer 3 is the owner of group of organic farms that cover an area of 200 acres in total. The farms grow vegetables, field crops like corn and soybeans, and small grains like rye and oats.

METHOD

In the course of this study, we collected data that accurately captured current farming practices, current perception of UAVs, and the scope of their operation. Understanding how farmers feel about UAV technology and their willingness to adopt it has implications for UAV design and development.

The data was collected exclusively through interviews. After exchanging emails with Cooperative 1, we visited the cooperative’s field office where we interviewed a representative from the Agronomy department. For Cooperative 2, we recruited and collected our data from them as a response to a questionnaire through email. In the case of Farmer 1, we recruited them at a Farmer’s Market and interviewed them at their farm. We recruited Farmer 2 for the study through email, and interviewed them at their office on campus. As for Farmer 3, we recruited them at a Farmers’ Market and conducted our interview through a phone call.

The interviews were structured around a pre-prepared list of questions that targeted the specific stakeholder. The interviews were recorded after receiving the consent of the participants. After brief introductions of each team member and a general overview of the project, the participants were asked questions from the pre-prepared list. Interviews progressed naturally in the form of conversation and new questions frequently arose during each discussion. We began by asking participants minimal objective data, such as the size of their farm or service area as well as the number of people they employ. The majority of the data we collected was subjective, such as questions designed to gain an understanding of agricultural practices, perceptions of UAVs, and current uses of technology. At the end of each interview, participants were given an opportunity to provide us with any further information as they saw fit. The interviews typically lasted about 30-40 minutes each. No compensation was provided. In addition to the audio recording of the interviews, field notes were also collected.

Analysis

A Grounded Theory approach was used to analyze the textual data transcribed from the audio recording of the interviews and field notes. An open coding process was first performed, during which codes were assigned to the participant's responses. After completing the process of open coding, to establish inter-rater reliability, a second and a third researcher used the provided dictionary to code a portion of the data. The inter-rater reliability showed substantial agreement between the secondary and the tertiary coders (75% agreement, κ = 0.72). Following this step, axial coding was used to identify phenomena, such as repeated events or views among the codes. In total, 24 axial codes were developed to capture the current agricultural scenario and scope for UAV use in rural Wisconsin. Ultimately, a selective-coding process was employed to understand the relationships between the axial codes developed, followed by comparative analysis and theory-building.

FINDINGS

Equipment Investments

A theme that stood out in our analysis was the emphasis on equipment and maintenance costs. Equipment is a considerable investment for farmers and cooperatives alike. Purchases are need-driven and not impulsive. Selecting the appropriate equipment and model requires extensive research and discussion with experts. Different models imply a different price-to-feature trade off. Farmers may rely on cooperatives to aid in their equipment decisions, particularly if the equipment must be customized for the farmer's needs. Equipment rentals are not always practical from the cooperative standpoint, as described in the following excerpt.

Cooperative 1: One size doesn't fit all when it comes to some equipment. So, it's just better if they own it so it's tailored to what they need. We don't order a bunch of extra parts; we have to rent to them. If we rent the equipment and they don't want to rent it anymore or we need to move on to something else, now we've got a whole bunch of outdated obsolete parts in our inventory. So that's just not good for business.

Just as farmers rely on cooperatives, cooperatives may develop relationships with manufacturers and sales consultants to hear an expert opinion on the best equipment fit, as illustrated in the following excerpt.

Cooperative 2: We spent a good amount of time researching the various devices and developed a relationship with a retail sales group that provided our team with guidance on selecting the proper model [UAV] to utilize in our current operations.

The initial purchase is only one piece of the overall equipment investment. Depending on the machinery, equipment may require regularly scheduled maintenance and on-demand repairs. Many farmers opt to complete maintenance responsibilities on their own, but such tasks can take farmers away from time-sensitive demands. For example:

Farmer 3: Repairs are, there's some welding, some things break, we kind of just work them through. Cause we don't have time to take them apart and fix them so. It's mostly maintenance like oil changing and lubrication painting that kind of thing.

Therefore, maintenance and upkeep can represent a significant investment of a farmer's time, and this must be taken into account for any new equipment acquired. This applies in decisions about precision agriculture equipment, including UAVs. As equipment becomes more technical, do-it-yourself repairs become less feasible, potentially increasing time and financial burdens. The risks of equipment damage, equipment failure, or software defects do not represent trivial financial implications.

Familiarity and Opinions

Our analysis revealed low awareness of UAV agricultural offerings among farmers. Participants who weren't familiar with the term "UAV" tended to be familiar with the colloquial term "drone" after we explained the definition of the term "UAV". Farmer 3 had read articles about using UAVs to fly over fields and look for diseases. Farmer 1 had previously seen a professional photographer's work using UAVs in the Amazon. Farmer 2 expressed disapproval of the use of UAVs in the military.

We asked farmers if they could see themselves using UAVs in their work now or in the future. Farmer participants each showed skepticism on the applicability of UAVs for small-scale farms for the current state of the art. They were unclear how they could use UAVs in a way that would add value on a smaller scale, as illustrated in the following excerpts.

Farmer 1: It's pretty cool! I'm not sure how I would use it in my operation yet.

Farmer 2: Probably not [it wouldn't have an impact]. On a larger scale is really where it matters a lot more.

Farmer 3: Not for my farm probably, because it's not that big. The fields are not that big, and we go in them all the time with the tractor anyway.

Because their fields are small, participants noted that it is not challenging to be aware of what is going on in each area. Depending on the season, farmers may be in the fields every day of the week. It is important to note that the farming methods described by participants were very hands-on and experience focused. Learning from others in addition to one's experiences in previous years was a common approach mentioned by all three farmers. Furthermore, the farmers we studied frequently rely on knowledge from their physical senses in order to maximize yield and mitigate threats. Even with this intuition, there is still a "trial and error" aspect to farming. For example:

Farmer 2: You can infer a lot of things just from going there, taking a shovel, feeling it with your hands, and looking around, but you really need to plant to see what problems are there. Soil samples help but there's still other variables.

When we asked farmers about ways that a UAV could be helpful to them, most thought of it as a way to narrow their focus to a particular region of their field, particularly through visualizations. Once a problem region was identified, farmers could address the problems using existing methods from that starting point. The distinction is that the UAV alone would not resolve an issue, but it would provide the farmer with useful data in an efficient manner.

Beyond general surveillance tasks, farmers were unsure what capabilities UAVs currently have. They also conveyed uncertainty on the type of data that a UAV can provide. Despite being uncertain of current offerings, farmers and cooperatives were clear about the features they would like to see. The ability to monitor weather conditions and soil conditions was a common request. For weather conditions, participants mentioned the desire to visualize wind patterns, air temperature, and humidity. Considering soil uses, participants brought up their wish to see patterns of water run-off, land erosion, soil moisture, and soil temperature.

Automation was another popular theme among UAV applications. Participants indicated a preference toward an autopiloted UAV as opposed to a remote-controlled application from an efficiency and timing perspective. For example:

Farmer 2: I think many farmers would feel as if they don't have the time to fly two to three hours a day. They'd probably have to do it at the time of day when you'd be doing other things.

An alternative method to the autopilot approach is to establish UAV operation as a separate job responsibility, such as another task for a farm manager, or a contracted service from a cooperative. For instance:

Farmer 3: With a farm this size I'd probably have to hire someone to do it [fly the UAV] anyway.

Farmer 1: I would love to be able to have a farm manager with [UAV] tools in hands. As small as this [farm] is, you can't be everywhere.

Both of the cooperatives we spoke to have had considerable exposure to UAVs and other precision agriculture technology. Based on their experience, they offered more concrete improvements to existing technologies. Cooperative 1 stressed the need for more durable mechanical components and longer battery life:

Cooperative 1: Having a weatherproof motor would be helpful. You know sometimes you don't know when its going to rain or if you're gonna get a spot shower. The quadcopters we've been using, they've got exposed motors in each corner. A light sprinkle and we fried two motors. Those are five hundred bucks apiece. So, that would be helpful from that standpoint.

Cooperative 1: Battery life is a concern. We've only got, I think there's four batteries or five that gives a total of an hour and fifteen minutes of flight time. You can't get a lot done in an hour and fifteen minutes. Granted, it's better than walking, but we don't get a lot done in an hour and fifteen minutes.

Despite varying familiarity, most participants in our study exhibited high enthusiasm and excitement about the future of UAVs. They were open to the possibility of using UAVs in agriculture even if they weren't clear exactly how they could be used on smaller scale farms. Two farmers mentioned that they "definitely" could see UAVs being used on their farms in the future.

Cooperative Involvement

Another prominent finding from our analysis was that many farmers depend on cooperatives to guide their technology investments. Cooperatives reported considerably more farmers looking to them for technology guidance than farmers implementing technology on their own, as shown in the excerpt below.

Cooperative 1: We got people that rely on us, 100% through-and-through to bring the technology to them, how to use them, what to do with the datathat's probably the higher percentage. We have a smaller percentage; maybe less than 2

Cooperatives can also bridge the gap between farmers and technology from a readiness perspective. People may not be "technology ready" if they experience a great deal of discomfort with technology[7]. Introduction of new technology by cooperatives can ease this discomfort and encourage adoption. This is a common task for cooperatives today, as highlighted by the example below.

Cooperative 1: They [traditional farmers] are really good at some of the other things in their operation...But when it comes to technology and data management and generating quality information, quality data, they shy away from some of that. So our job is to make them comfortable with technology that's out there.

By design, cooperatives are in the unique position of being able to offer services to farmers without requiring significant upfront costs from the farmer. As precision agriculture technologies enter the market, the practice of offering this technology as a service reduces the barrier to entry. The cooperatives that we spoke with emphasize their commitment to being at the forefront of new technology, as demonstrated in the following excerpt:

Cooperative 2: Currently we are fully and amply equipped with the most up to date and technology advanced application equipment utilizing precision technology. We continually monitor and evaluate various new advancements in the application equipment industry looking to maintain the cutting edge of that type of equipment.

The combination of cooperatives staying up to date on the latest technology, their unique relationships with farmers, and the cost benefits of offering precision agriculture as a service makes them an ideal candidate to introduce and promote UAV technology. Several participants share this viewpoint:

Farmer 3: Coops, I think they'd probably be the people that would do it [offer UAV operation as a service].

Farmer 2: It seems to me that it would make a lot of sense to collaborate with local entities in that regard [using UAVs].

Cooperative 1: I see them [UAVs] being a part of some of the higher end services we offer customers, if and when it's ever allowed

It is worth noting that none of the three farmers we spoke with currently worked with cooperatives in the area. One farmer mentioned a perceived incompatibility between co-ops and small-scale farms:

Farmer 1: I'm not opposed to working with them, but they're not geared toward the small operatorBig co-ops haven't figured out how to deal with us [small farmers]I know who they are and I'm not afraid to talk to them, but I'm not sure they have a lot to offer me.

It is unclear what, if any, impact the lack of involvement between small-scale farmers and co-operatives will have on UAV adoption for small-scale farmers.

Views on Government Regulation

As previously outlined, UAV legislation remains a controversial issue. At the state level, Wisconsin has legalized the use of UAVs that are not weaponized, not flown in spaces that interfere with normal use, not flown in privately owned property without owner consent, and not flown in places where individuals have a reasonable expectation of privacy [3]. More granular government regulations on the use of UAVs for commercial agricultural practices have yet to be announced at either the state or federal level. Participants indicated that they expect new legislation in 2015.

Without knowing what their limitations will be, participants expressed concern about what decisions will be made in the future and how this will impact the role of UAVs on private farms. For example:

Cooperative 2: Many of the concerns at this point would be just waiting to see what the FAA guidance becomes in 2015.

There is a perceived risk of new laws causing a negative impact on the return on investment. Depending on how restrictive new laws are, cooperatives may need to revise their business plans within their precision agriculture divisions. For some, the undefined state of legislation is slowing or halting their investment in UAVs. For instance:

Cooperative 1: I'd like to see what's gonna happen with regulation [of UAVs], before we start biting off big chunks of money before we start investing in something like that and really kinda trying to blow it up, we need to know what our restrictions are.

Legislative decision has high stakes for farmers and cooperatives that are interested in using this technology, especially those who have already begun making use of it. This is not to say that participants oppose legislation. In fact, many participants expressed their support for some level of regulation. Two participants suggested a need for qualification controls, as illustrated in the following excerpts:

Farmer 2: I feel like there would have to be definitely some sort of training and assessment of individuals or collaborative groups that are using that technology. They would have to continue to be assessed on an annual or bi-annual basis.

Farmer 3: I don't think it would be a problem to restrict it that you would need, that you would need to be trained. To have some set of rules you know, yeah. Like certain people find it useful and they should be able to use it mostly.

On the other hand, the threat of over-regulation remains a concern. This trend persists among cooperatives and farmers alike, with cooperatives concerned about ROI for existing and future operations and farmers not wanting the government to interfere in their work. For example:

Farmer 1: I would hate to see the FAA take over the drones. I've heard enough to know that's the last thing they need.

Farmer 3: I suppose it could be a problem if it gets too restrictive, especially if you're a farmer by the city probably. I don't know how they are planning on restricting it so I don't know how much of a problem it would be.

At the corporate level, cooperatives are expressing their needs and working with lawmakers to develop legislation. On a local level, two participants reported interacting with farm bureaus to have their voices heard. Several participants reported that they actively follow legislative work in this area. For example:

Cooperative 1: They [Cooperative 1's parent company] are very heavily in the lobbying process with some of the regulations going on with that [UAVs]Several of our employees, myself included, sit on some of the local boards, county boards, and I know that's going to be a big focus for the Wisconsin Farm Bureau as well as the National Farm Bureau going into 2015. So certainly our voices are being heard that way.

Cooperative 2: We continue to monitor the legislative work around UAV usage, especially with respect to agriculture operations.

Discussion and Design Implications

Among the small farmers that we spoke to, each farmer had difficulty envisioning how they could get value out of using a UAV in their current operations. In this section, we will explore possibilities for future uses based on our findings and understanding of current practices.

It was a common trend for farmers to have minimal data management. Several participants captured data about sales, but other records were lacking, including historical, input-supply, and climate data. UAVs can automate the collection of large amounts of this data. While it is not clear if this will influence a farmer's behavior, the potential impact of UAVs is not limited by current data management practices. UAVs can benefit farmers regardless of record keeping. For example, a farmer may take an action based on a live feed from a UAV, without the dependence on any historical data.

Farmers are constantly dealing with threats to their crops. Among the farmers we spoke to, weather, insects, larger pests, and disease were primary challenges that they had to counteract. Mitigation attempts tended to be reactive: when a plant starts showing observable symptoms, appropriate steps are taken. Proactive methods could be utilized if more precise data is available before the threat becomes serious. UAVs would deliver accurate, real-time information that would provide early indicators of a threat. For instance, a UAV equipped with a thermal camera may be able to detect fungal disease based on increased heat in the affected area as the plants attempt to fight the threat.

Throughout our interviews, participants were eager to suggest design features that would help them see more value in UAVs. Suggestions included features to make the UAV more durable, such as weatherproof motors and longer battery life. Automated features were also in high demand: participants indicated a preference for a pre-programmed autopilot mode based on GPS coordinates of their fields. However, several individuals noted that a manual override would also be necessary for certain circumstances, including experimental use and backup in case of autopilot failure.

CONCLUSION

Although we did not have any statistical analysis to test any hypotheses, this ethnographic study proved to be useful in evaluating key concepts for exploration in the future. The trends identified above can be used as a bridge between creators and farmers, informing the design process and providing insight into the potential uses and concerns surrounding UAVs. Complete systems can then be built with this information, allowing for fewer iterations in the product development process and a significantly more valuable tool for the farmer.

ACKNOWLEDGMENTS

We would like to thank the following people for their help and support with this study: the study participants, Bilge Mutlu, the UW-Madison HCI Lab, Thomas Butts, Jia Shen Boon, Isaac Sung, and the University of Wisconsin-Madison.

REFERENCES

1. A, G. J. G., B, A. E., and C, B. T. The photogrammetric potential of low-cost uavs in forestry and agriculture.
2. Administration, F. A. Integration of civil unmanned aircraft systems (uas) in the national airspace system (nas) roadmap, 2013.
3. Administration, F. A. *Unmanned Aircraft Systems (UAS) Frequently Asked Questions*, 23 July 2014 (accessed December 10, 2014).
4. Aerial, V. *Vortex Aerial*, 2012 (accessed December 10, 2014).
5. Amazon, I. Amazon prime air, 2013 (accessed December 10, 2014).
6. Association, U. A. V. S. *UAV or UAS?*, 2014 (accessed December 10, 2014).
7. Colby, C., and Parasuraman, A. *Techno-Ready Marketing: How and Why Customers Adopt Technology*. Free Press, 2001.
8. Cook, K. The silent force multiplier: The history and role of uavs in warfare. In *Aerospace Conference, 2007 IEEE* (March 2007), 1–7.
9. Frederick, D. A. Co-ops 101: An introduction to cooperatives. cooperative information report 55, 2012.
10. Legislature, W. S. *2013 Wisconsin Act 213*, 2013 (accessed December 7, 2014).
11. Odom, W. ”mate, we don't need a chip to tell us the soil's dry”: Opportunities for designing interactive systems to support urban food production. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems*, DIS '10, ACM (New York, NY, USA, 2010), 232–235.
12. Pablo J. Zarco-Tejada, J. A. J. Berni, L. S., and Fereres, E. *Remote Sensing: A new era in remote sensing of crops with unmanned robots*, 17 December 2008 (accessed December 10, 2014).
13. Stanley, J. *Drones vs UAVs Whats Behind A Name?*, 20 May 2013 (accessed December 10, 2014).
14. Sugiura, R., Noguchi, N., and Ishii, K. Remote-sensing technology for vegetation monitoring using an unmanned helicopter. *Biosystems Engineering 90*, 4 (2005), 369 – 379.
15. Williams, R. *Current Unmanned Aircraft State Law Landscape*, 16 September 2014 (accessed December 7, 2014).