A Survey of Drone Use for Socially Relevant Problems: Lessons from Africa

A. Nicki Washington
209 Thurmond Building, Winthrop University,
Rock Hill, SC 29733,
USA
Email: washingtonn@winthrop.edu

ABSTRACT

The predicted increase in commercial drone usage in the U.S. by 2021 has presented new opportunities to solve challenging problems where factors such as infrastructure, accessibility, and finances prohibit traditional solutions. While the U.S. and other countries across the globe research how drones can be used to solve these problems, countries in Africa are leading the current state of the technology through various efforts across the continent that provide critical solutions to socially relevant problems that directly impact people, wildlife, and the environment. In this study, we identify current drone implementations in Africa and current and proposed drone implementations in non-African countries. Given the much greater use of drones in Africa, we discuss the benefits and challenges to drone use, including the factors leading to Africa's many successes. Finally, the lessons learned are used to identify important considerations for the U.S. and other countries seeking to successfully leverage drone technology.

Keywords: *Drones, unmanned aerial vehicles (UAVs), Humanitarian Drone Testing Corridor, socially relevant problems*

African Journal of Computing & ICT Reference Format:

A.Nicki Washington (2018), A Survey of Drone Use for Socially Relevant Problems: Lessons from Africa, *Afr. J. Comp. & ICT*, Vol.11, No.3, pp. 1 - 11.

I. INTRODUCTION

Drones are unmanned aerial vehicles (UAVs) that are deployed in environments where manned flights are too dangerous, difficult, or expensive. They have gained increasing attention in recent years as a viable alternative to many problems where traditional solutions are prohibited due to infrastructure, economic, and other factors. While originally developed for military use, drones have expanded from intelligence, surveillance, and reconnaissance applications (where manned flights were too dangerous or incapable of traveling) to commercial and recreational purposes.

The U.S. Federal Aviation Administration (FAA) predicted that as many as 1.6 million commercial drones will be in use in the country by 2021 [28]. This presents opportunities to leverage technology to solve critical problems nationwide as well as globally that affect people, wildlife, and the environment. While the FAA has relaxed some drone restrictions in recent years, there are still regulations that limit their use in the country.

While the U.S. and much of the western world research the possible applications of drones, African countries have already successfully demonstrated their use for various non-military and non-commercial solutions to socially relevant problems. These efforts not only provide critical services, but also serve as an example for countries such as the U.S. on how to effectively leverage the technology.

In this study, we highlight the various non-commercial applications of drones throughout Africa. Specific emphasis is placed on non-commercial applications, as these provide clear roadmaps for how western countries can maximize the impact of the technology for socially relevant problems. This research seeks to identify how and where drones have been most successfully used. It was also important to understand why African countries have been able to successfully leverage this new technology well before other countries and what lessons could be learned from their results.

The remainder of this paper is organized as follows. In section 2, we define drones and classify the various types. In section 3, we first discuss the applications of drones in African countries, followed by the applications in non-African countries. In section 4, we discuss the reasons for Africa's leading edge in drone use, as well as the benefits and challenges of the technology. In section 5, we present future considerations for western countries to consider for global drone adoption, based on the successes and lessons learned throughout Africa. Finally, section 6 concludes the paper.

II. DRONE/UAV CLASSIFICATIONS

Depending on the organization, UAVs are classified into a number of categories based on size, range, and capacity. While U.S. organizations such as the Department of Defense, National Aeronautics and Space Administration, and North Atlantic Treaty Organization may use different naming conventions, the weight requirements remain relatively consistent. In this study, we classify drones according to the names and associated weight limits defined for UAVs by the U.S. Department of Defense for UAVs in Table 1 [14].

Small UAVs (more commonly referred to as mini- or micro-UAVs) are limited to a range of visual line of sight (VLOS) to 100 kilometers. Most commercial UAVs are classified in this category and range in price from $100 to over $100,000. Due to size limitations, micro-UAVs can be small enough to be carried via backpack or by one or two people.

Small UAVs can be further categorized as rotary- or fixed-wing, as shown in Table 2 [11]. Rotary-wing UAVs have lift generated by wings rotating around a mast. As a result, these UAVs are capable of vertical takeoff and landing (VTOL), hovering, and maneuvering in small areas. They are also easy to deploy and operate, as they require a minimal space for takeoffs and landings. However, the functionality of rotary-wing UAVs is more complex, which leads to several disadvantages. More complex functionality means that the operation and maintenance of these UAVs are expensive. In addition, they have a limited travel distance and speed. As such, their flight time averages between 10-15 min. Finally, they are more prone to environmental factors, such as rain and wind. As a result, rotary-wing UAVs are best used for applications that involve inspections, precision movement, and maintaining a visual on a specific target for an extended time.

Fixed-wing UAVs operate similar to airplanes, where a pair of wings connected to the fuselage creates lift. Their build is much less complex than rotary-wing UAVs, which makes them much cheaper to operate and maintain. In addition, their ability to glide allows for flight even when there is no power. These UAVs are also less impacted by environmental factors such as rain and wind, and they can sustain longer flight times averaging 90-120 min. However unlike rotary-wings, fixed-wing UAVs cannot remain stationary. Because of this, they also require a runway or landing strip for takeoffs and landings, which ultimately require more knowledge and skills to conduct than rotary-wing UAVs. Fixed-wing UAVs are most appropriate for applications that involve aerial surveys of large geographical areas or delivery of large payloads over longer distances.

Whether rotary- or fixed-wing, the affordability and ease of transport of small UAVs makes them the most applicable to solving many problems worldwide. As such, the focus of this study is on the use of small UAVs (hereafter referred to as drones) for various humanitarian, wildlife, and environmental solutions.

III. SUCCESSFUL APPLICATIONS OF DRONES

3.1. Applications of Drones in African Countries

Drones have been proposed or successfully used throughout Africa to solve problems in a number of areas, including:

- Healthcare
- Population and wildlife monitoring
- Agriculture
- Archaeology
- Genocide prevention

Each of these applications is discussed in more detail below.

3.1.1. Healthcare

Drones are used to provide critical life-saving aid (including medicine, food, water, and supplies) to remote areas in Africa where adequate facilities are not present or travel by foot and/or car is too long. In Rwanda, San-Francisco-based Zipline partnered with the Rwandan health ministry to deliver blood to hospitals where traditional medical supply lines are currently unreachable [9, 13, 17]. The company accepts orders for blood via web, text, phone, and What'sApp, which are then delivered via drones and dropped to awaiting recipients at each hospital using attached parachutes. In 2017, the service delivered more than 5,500 units of blood to a network of 12 hospitals using 15 UAVs. This network has successfully delivered life-saving aid to over 5 million people, thereby reducing maternal deaths due to blood loss from childbirth and malaria-induced anemia (which has higher occurrences in children). This work will soon expand to Tanzania, where 120 drones will provide supplies to 1,000 clinics serving approximately 10 million people. In Malawi, Ghana, and Madagascar, HIV test kits, birth control, condoms, medical supplies, TB tests, and blood and DNA samples are delivered to and from rural areas to base stations in more urban areas [1, 8]. These efforts have significantly improved healthcare and quality of life for many residents across the countries, especially women. Most recently, drones were used to identify cholera hotspots in Malawi's capital of Lilongwe.

3.1.2. Population and Wildlife Monitoring

In an effort to combat the poaching of endangered rhinos and elephants, South African rangers and the Namibian Defence Force fly eco-drones that use satellite imagery, predictive analysis, and hidden cameras over game reserves to monitor animal activity and predict, locate, and track suspected poachers [12, 20, 32]. Eco-drones are also used to monitor the impact of climate change and deforestation, as well as migration patterns on both land and marine animals. In Morocco, illegal maritime activities and oil spills are also tracked and monitored using drones [5].

In Ethiopia, the Tsete fly is responsible for transmitting sleeping sickness, which results in significant human, animal, and agricultural losses [2, 20, 23]. The Ethiopian government currently works with private organizations to utilize the sterile insect technique to eradicate the fly population. Using drones, sterile Tsete flies are released into specific regions on a weekly basis. The goal of this process is to mate the sterile flies with non-sterile ones, thereby reproducing more sterile flies and ultimately eradicating the Tsete fly and disease.

3.1.3. Agriculture

Desertification threatens close to 70% of Sudan's agricultural land due to decades of drought and deforestation [5]. The effects of climate change due to deforestation mean that a large majority of Sudan will eventually become uninhabitable if significant and intentional actions are not taken to address it. To combat this threat, drone solutions were developed to first plant Acacia tree seeds from the sky and then conduct plant health assessments via remote sensing. Acacia tree roots stop sand movement, which in turn thwarts the devastation of homes and farmland. Researchers and other non-government organizations can also more closely monitor the impact of these efforts using drone technologies than traditional ground efforts. In Mauritius as well, crops are closely monitored via drones to detect issues such as water shortages and pest infestation, thereby allowing farmers to reduce crop losses and maximize harvests. In Kenya and Tanzania, drones are being researched as a means to digitize the countries' land information systems [15, 16]. In Senegal, they are leveraged as a means to identify grazing and watering areas for the Fulani mobile livestock producers [4].

3.1.4. Archaeology

The ability of drones to provide aerial views of the topography has encouraged their use for detecting, mapping, and viewing archaeological sites in the Yoruba civilization of Nigeria [5]. Drones were used to identify sites for excavations much better, faster, cheaper, and exhaustively than ground-based efforts.

3.1.5. Genocide Prevention

Drones can also be used to assist global humanitarian efforts to reduce and eliminate human genocide, which still plagues many areas, including Sudan, Nigeria, Kenya, and parts of Asia, including Burma, Syria, Sri Lanka, and Kyrgyzstan [35]. The Sentinel Project proposes to use drones to predict when and where atrocities are most likely to occur, reduce the risk of occurrences, and work with communities to increase resilience and reduce the impact of them [28]. Drones could also be used to identify exact locations of atrocities, document ongoing ones, and provide early warnings, thereby improving the reaction time to impending atrocities.

3.2. Applications of Drones in Non-African Countries
Majority of the non-commercial applications of drones in non-African countries have focused on first response to natural disasters. However, following the success of the many efforts in Africa, countries are now researching larger applications that emulate some of the aforementioned ones.

3.2.1. Natural Disasters
According to the United Nations Office for Disaster Risk Reduction, natural disasters have affected over 3 billion people worldwide, causing approximately 1.2 million deaths and $1.7 trillion in damages [10, 30]. The Haiti and Nepal earthquakes, Japan and Indian Ocean tsunamis, and most recently Hurricane Maria each caused severe damage, killing thousands and destroying property throughout. The most immediate need for emergency responders following a natural disaster is situational awareness. Without proper assessment of and accessibility to damaged areas, resources such as food, water, and other life-saving measurements and activities are delayed [3]. This makes the first 24-72 hours following a disaster the most critical for life-saving missions.

Drones have been successfully used to assist in various time-critical emergency response efforts where manned aircrafts are too expensive or large to be useful [18] and are also proposed in new areas.

Data Collection and Observation-One of the most immediate uses of drones is to better assess the extent of the damage following a natural disaster, which cannot be easily determined via ground efforts. This includes providing images and videos of difficult or impossible to reach areas (such as damaged infrastructure and blocked roads), as well as any continued monitoring of impeding weather-related threats. While these were previously accomplished using manned aircrafts and satellite information, this was often expensive and lengthy in time, two factors that hinder first response efforts.

Search and Rescue (SAR)-Increasing research is focused on the use of drones for search and rescue (SAR) efforts across the globe. The European Union funded several SAR projects, including the SHERPA project, which developed ground and aerial robots to assist in alpine SAR [7, 27, 33]. The ICARUS project was also created to provide unmanned technologies for both urban and maritime SAR efforts. The goals of the ICARUS project were to reduce slow deployment times and increase integration and collaboration between unmanned devices. In the U.S., new Federal Aviation Administration (FAA) regulations on civilian drone usage has made it possible for individuals to assist in SAR efforts in their local communities [18]. However, there are still requirements for private operators to use their drones for emergency response efforts, which may hinder their ability to quickly assist in efforts.

3.2.2. Healthcare
In Switzerland, Matternet partnered with the Swiss Post to create a permanent autonomous drone network that delivers medical supplies in Lugano, Bern, Zurich, and other cities [19]. In Sweden, drones carrying automated external defibrillators (which send an electrical shock to heart of patients in cardiac arrest) were shown to reduce the response time to out-of-hospital cardiac arrest victims in rural areas, when compared with emergency medical services on the ground [6].

3.2.3. Active Shooter Response
With the increasing occurrence of mass shooting incidents in the U.S., many researchers are advocating the use of drones to help prevent and respond to these incidents [24]. Drones could be deployed at major events, especially those outdoors, to provide additional surveillance capabilities. This would help law enforcement better identify potential shooters and, should an incident occur, researchers propose that drones can be used to distract or assist in disarming active shooters. In cities like Boston, law enforcement officials are also researching the use of surveillance drones and facial recognition software to capture 24-hour footage on suspects, similar to surveillance cameras [25]. Unlike surveillance cameras or CCTVs (which are currently implemented in many cities throughout the U.S.), the use of drones would allow for better coverage of areas, due to their mobility. Current technologies are stationary, which can provide limited surveillance based on the stationary camera's coverage area. Movable drones would provide wider and more accurate coverage for use by law enforcement officials.

IV. AFRICA'S IMPACT ON DRONE TECHNOLOGY

One of the major reasons that drone use has exploded in Africa is that governments identify the advantages and are more accepting of it across various industries, as opposed to the strict regulations in western countries. Governments are more willing to test new technologies, especially when they have the potential to significantly impact the country. In 2017, the Government of Malawi and UNICEF partnered to create the Humanitarian Drone Testing Corridor, the world's largest test area designed to explore the development and use of drones for humanitarian efforts. The area spans over 5000 sq. km and up to 400 m above ground level, and provides opportunities for industry, universities, and others to safely explore how drones can be leveraged to provide relief and deliver services to underserved and hard to reach areas of the country [22, 31].

The corridor focuses on three major areas: 1) generating and analyzing images for development during humanitarian crises; 2) exploring the use of drones for extending Wi-Fi or cellular signals across difficult terrain, including emergencies; and 3) delivering small, low-weight supplies (e.g. medicine, vaccines, and samples) [31].

Many drone development companies, especially those in the U.S., recognize and appreciate the opportunity to fully implement their products, especially when they are used to directly impact citizens, wildlife, and the environment. As Zipline CEO Keller Rinaudo noted, "…It's more about the countries with modern regulatory reform and willingness to try new things" [17].

In Tanzania, permits from the aviation authority and minister of defense are required to operate drones. In addition, all drones must remain below the altitude of and an adequate distance from traditional planes to ensure safety and maneuverability. Other countries such as South Africa and Kenya are developing legal frameworks to closely control the use of drones. However, these restrictions are minimal compared to the numerous restrictions in place in the U.S. As long as the aforementioned requirements are met, the use of drones is acceptable for smaller, non-commercial and non-military applications.

A significant limitation in the U.S. is the restriction to visual line of sight (VLOS) [26]. If this remains a requirement for current and future operations, then travel distances will remain significantly less than the maximum capabilities of Zipline drones, for example. The bureaucracy of the FAA does not lend itself to rapid technological development, which results in slower acceptance of drone usage in the U.S [34]. Currently, companies can apply for special exemptions [1]. However, these exemptions are mostly limited to large commercial organizations. While technological development of drones still continues in the U.S., particularly in Silicon Valley, the application of the technologies lags significantly behind.

This resorts in many of the leading drone developers and researchers in the U.S. searching for areas where the technology can not only be properly tested outside of the country, but also implemented to solve real problems. Given the legal and ethical limitations of the U.S., many of the advancements experienced in Africa will be unavailable in the U.S. until regulations are updated to allow more drones to travel beyond VLOS to deliver goods and services.

4.1. Benefits of Drones

Given the various global applications of drones, there are several clear advantages they provide, when compared with manned aircrafts.

Accessibility- Drones have provided ease of accessibility to difficult to access or inaccessible areas, including remote villages and rural areas. For healthcare-related applications, this has provided technological, medical, and other related life-saving aid to individuals who may not otherwise receive it. It also provides vantage points that are difficult or impossible to obtain from individuals on the ground with limited line-of-sight, or manned aircrafts, which are too large.

Faster Response Times-Drones in Sweden can fly up to approximately 75 km/h within a six-mile radius, delivering automated external defibrillators 16 minutes faster than emergency medical services in rural areas [6]. Zipline drones in Rwanda can travel up to 96 km/h within a six-mile radius [35]. Given the poor road conditions in the country, the response time for delivering blood supplies is reduced from up to four hours by car to 20 minutes via drones. Since blood spoils quickly, these faster response times inevitably mean better treatment for patients and increased survival rates.

Inexpensive- Drones are much less expensive than manned aircrafts, allowing for easier deployment in remote areas across the globe. Matternet announced that each drone and automated base station will be leased monthly for $2,000 each [13]. This is expected to save Swiss hospitals as much as 40% of their current monthly costs of on-demand delivery. The availability of drones at various price points means that even emergency response efforts can be implemented at much cheaper costs than those requiring the use of manned aircrafts.

Community Collaboration-While the use of drones is still prohibited for civilian use in many countries, new advancements and opportunities will make it possible for individuals to own and operate drones to aid in many of the aforementioned efforts. In the U.S., the FAA regulations on recreational drone usage have made it possible for individual citizens to help in some limited SAR efforts [21]. As more regulations on recreational drone usage are enacted around the globe, the ability to incorporate local citizens into humanitarian, wildlife, and emergency response efforts will continue to grow.

4.2. Challenges to Drones

While there are numerous benefits to using drones, there are still significant challenges to address as well.

National Responsibility Concerns-There are growing concerns that the successful launch of drone projects in certain parts of the world will reduce nations' accountability for providing citizens with adequate resources, including infrastructure. As with many new technologies, there is the possibility of dependence on the technology instead of properly addressing the problems that the technology helped to reduce or eradicate. For example, the introduction of Zipline drones for critical blood supply deliveries helped to address the issues associated with extremely difficult, if not impossible vehicle delivery in Rwanda due to bad road conditions and difficult routes (including rainy seasons). Solutions such as Zipline should not remove or reduce government responsibilities to provide adequate infrastructure and resources to citizens. Instead, they should serve as a supplement to aid citizens while nationwide improvements are implemented.

Properly Trained Operators-Proper usage of drones requires an adequate number of trained/authorized onsite operators [18] at the base stations, at a minimum. This challenge presents a unique opportunity to not only train but also employ local citizens with the requisite skills to scale the technology throughout the region and country. This also presents an opportunity to introduce more science, technology, engineering, and math (STEM)-based activities into local schools.

Equipment Loss or Damage-Varying weather conditions, operator errors, or equipment malfunctions are not uncommon for drones and can result in lost or damaged equipment. Inoperable equipment reduces the number of successful deliveries and should be properly planned for.

Limited Distances and Weight Capacities-The size and maximum flight times of drones limit the distance they can travel and amount of goods they can properly transport. Most drones discussed in the aforementioned efforts are less than 25 lbs. and the maximum flight times experienced have been approximately 75 minutes. This requires careful planning to reach the maximum number of recipients as possible.

Government Regulations-As the use of drones continues to grow for both recreational and non-recreational purposes, countries are forced to address concerns regarding safety and liability. More urban areas face stricter regulations on drone usage, as airspace must typically be shared with manned aircrafts. Many countries have regulations prohibiting the operation of drones within a certain distance of airports and other areas that may impede on government-related efforts. However, with the growing applicability of drones to solve a number of the aforementioned efforts, proper regulations must be enacted that allow for safe use of drones. While there may never be a single framework that works for every government, it's imperative that each country identify and create the appropriate regulation that ensures the introduction of the technology in a safe and legal manner.

Privacy Concerns-The amount of information that can be captured by small drones can present privacy concerns for local citizens. This is especially true for humanitarian efforts, where sensitive information may be captured. This will also require properly educating citizens on drone technology, including the information that is gathered and what it is used for. This requires governments to properly engage communities prior to full deployment of drone solutions.

Limited Time-to-Deployment-Many of the aforementioned efforts that successfully used drones required the aircrafts to be immediately deployed. For search and rescue efforts, this requires having first responders available with the necessary equipment to quickly deploy drones immediately following a natural disaster. While this may be easier to accomplish in some situations, damaged infrastructure for example may not warrant this as easily. For proposed efforts involving disarming active shooter situations, this requires both law enforcement officials to not only be available before an incident, it also requires those officials to have the aircrafts with them and the requisite training to deploy them in a fast enough time to address an active shooter.

V. CONSIDERATIONS FOR FUTURE DRONE USAGE WORLDWIDE

As drone usage continues to grow worldwide, a number of considerations must be addressed to ensure the proper and safe use of this technology.

5.1. Regulatory Framework

Each country must determine the appropriate legal and regulatory framework that ensures safe and ethical operation of drones in their country. This includes non-interference with commercial and government aerial vehicles, as well as ensuring the protection of citizens' privacy. This may require the use of special exemptions that are applied in instances such as first response and humanitarian efforts in emergency situations, to allow for all available and qualified drone operators (including private citizens) to assist.

5.2. Community Engagement

Part of the regulatory framework must define how drone usage will ensure citizens' rights to privacy [34]. However, this work will still require active engagement with the public to ensure that citizens fully understand how their privacy is maintained and build trust in the use of drones in non-emergency settings especially. In addition to this engagement, there is a significant opportunity for governments to help train and prepare citizens to become drone operators. This includes creating science, technology, engineering, and mathematics (STEM)-based curriculum and educational opportunities in local schools. This also presents opportunities to train adults to become operators at base stations, allowing for the expansion across countries.

5.3. Partnerships

Governments must form partnerships with companies developing drone technology across the world. While large organizations such as Lockheed Martin, Boeing, and Northrup Grumman have led drone development for military efforts, many smaller companies such as Zipline, Matternet, GoPro, and Parrot are currently developing and implementing solutions across the world that leverage small drones to solve socially relevant problems. Proper partnerships must also include other agencies, universities, and researchers focused on humanitarian, environmental, and wildlife efforts. These partnerships will help to drive innovation in drone development and usage in each of the aforementioned areas.

5.4. Redundancy

Proper planning must include funding for redundancy. Since drones can be easily damaged, replacement equipment must be available to ensure adequate service is still provided with minimal downtime.

5.5. Community of Practice

Developing a community of practice that identifies best practices across the world is needed to help further guide countries developing regulatory frameworks and drone developers and users. While there are small initiatives based on specific applications of drones, a larger community of practice that encompasses all applications and the best practices within each application and overall should be considered to help easily guide new governments, agencies, developers, and researchers looking to enter the field.

VI. CONCLUSIONS

As the non-military use of drones continues to increase, countries and governments are exploring the applications of the technology to solve critical problems in a number of areas. However, countries in Africa have led the successful implementation of drones to provide socially relevant solutions to problems that span a wide range of areas. Given less stringent regulations and more government partnerships with leading drone development companies (including designating testing areas for drone research), Africa has provided a blueprint for how the rest of the world can leverage this technology to solve relevant problems that benefit citizens, wildlife, and the environment.

Following the successful implementations across Africa, many countries across the world are now looking to replicate these efforts to provide better services to citizens, including the U.S. and several in Europe. While there are a number of advantages to drone use, there are also a number of challenges to consider and properly address. Careful consideration of the limitations and how to best address these prior to nationwide drone implementations will help governments ensure that the technology can be properly exploited while minimizing safety risks, costs, and privacy concerns.

REFERENCES

1. Balasingam, M. (2017). Drones in medicine-The rise of the machines. The International Journal of Clinical Practice, 71(9). https://doi.org/10.1111/ijcp.12989.
2. Berie, H.T and Burud, I. (2018). Application of unmanned aerial vehicles in earth resources monitoring focus on evaluating potentials for forest monitoring in Ethiopia. European Journal of Remote Sensing, 51(1):326-335.
3. Center for Robot-Assisted Search and Rescue. Retrieved May 7, 2018, from http://crasar.org/category/research.
4. Chiderov, T. and Ryley, T. (2015). Drones in Africa? Targeted climate change mitigation in Senegal's agro-pastoralist communities. 3rd International Conference on Sustainable Development Practice (ICSD).
5. Child, D. (2018). From Kigali to Khartoum: Africa's drone revolution. Retrieved May 7, 2018, from https://www.aljazeera.com/indepth/features/africa-drone-revolution-180123090528801.html
6. Claesson, A., Backman, A., Ring, M., et al. (2017) Time to Delivery of an Automated External Defibrillator Using a Drone for Simulated Out-of-Hospital Cardiac Arrests vs Emergency Medical Services. Journal of the American Medical Association, 317(22):2332-2334.
7. De Cubber, G., Doroftei, D., Baudoin, Y., Serrano, D., Chintamani, K., Sabino, R., and Ourevitch, S. (2012). ICARUS: Providing Unmanned Search and Rescue Tools. Retrieved May 15, 2018, from http://www.fp7-icarus.eu/sites/fp7-icarus.eu/files/publications/Providing%20Unmanned%20Search%20and%20Rescue%20Tools.pdf
8. Drones for Development. Retrieved May 7, 2018, from https://www.dronesfordevelopment.org/.
9. Glauser, W. Blood-delivering drones saving lives in Africa and maybe soon in Canada (2018). Canadian Medical Association Journal, 190(3): E88-E89.
10. Guha-Sapir, D., Hoyois, P., Wallemacq, P., and Below, R. (2017). Annual Disaster Statistical Review 2016: The numbers and trends. Retrieved May 7, 2018, from https://reliefweb.int/report/world/annual-disaster-statistical-review-2016-numbers-and-trends.
11. Gupta, L., Jain, R., and Vaszkun, G. (2015). Survey of important issues in UAV communication networks. IEEE Communications Surveys and Tutorials, 18(2):1123 - 1152.
12. Hodgson, J., Mott, R., Baylis, S., Pham, T., Wotherspoon, S., Kilpatrick, A., Segaran, R., Reid, I., Terauds, A., and Koh, L. (2018). Drones count wildlife more accurately and pricesely than humans. Methods in Ecology and Evolution. Retrieved May 15, 2018, from https://doi.org/10.1111/2041-210X.12974.
13. Hotz, R. (2017). In Rwanda, Drones Deliver Medical Supplies to Remote Areas. Retrieved May 7, 2018, from https://www.wsj.com/articles/in-rwanda-drones-deliver-medical-supplies-to-remote-areas-1512124200.
14. International Civil Aviation Organization (2011). Unmanned Aircraft Systems (UAS). Retrieved May 7, 2018, from https://www.icao.int/Meetings/UAS/Documents/Circular%20328_en.pdf.
15. Kameri-Mbote, P. and Muriungi, M. (2017). Potential contribution of drones to reliability of Kenya's land information system. The African Journal of Information and Communication, 2017(20):159-169.
16. Lichtman, A. and Nair, M. (2015). Humanitarian uses of drones and satellite imagery analysis: The promises and perils. AMA Journal of Ethics, 17(10):931-937.
17. McFarland, M. (2017). East Africa is leading the world in drone delivery. Retrieved May 7, 2018, from http://money.cnn.com/2017/08/24/technology/east-africa-drones/index.html.
18. Meis, N. and Davis, T. (2016). Drone Operations Aid Emergency Response. Retrieved May 15, 2018, from https://www.pobonline.com/articles/100593-drone-operations-aid-emergency-response.
19. Mohammadi, D. (2017). Fledging drone technology bringing medicines to remote regions. The Pharmaceutical Journal. Retrieved May 15, 2018, from https://www.pharmaceutical-journal.com/news-and-analysis/features/fledgling-drone-technology-bringing-medicines-to-remote-regions/20203244.article.
20. Mulero-Pazmany, M., Stolper, R., van Essen, L.D., Negro, J., and Sassen, T. (2014). Remotely

piloted aircraft systems as a rhinoceros anti-poaching tool in Africa. PLoS ONE 9(1): e83873. https://doi.org/10.1371/journal.pone.0083873.
21. Muoio, D. (2016). How drones are turning everyday citizens into superheroes. Retrieved May 7, 2018, from http://www.businessinsider.com/new-faa-rules-help-drone-search-and-rescue-workers-2016-8.
22. Reuters Staff (2017). Malawi, UNICEF launch Africa's first humanitarian drone testing corridor. Retrieved May 7, 2018, from https://www.reuters.com/article/us-malawi-aid-drones/malawi-unicef-launch-africas-first-humanitarian-drone-testing-corridor-idUSKBN19K1Q3.
23. Romero, D. (2017). Could drones take out mass shooters? Retrieved May 7, 2018, from http://www.laweekly.com/news/could-drones-be-a-new-weapon-against-mass-shooters-8716648.
24. Rise Africa Rise (n.d.). Drones will change Africa. Here is how. Retrieved May 7, 2018, from https://riseafricarise.com/drones-will-change-africa-here-is-how/.
25. Rosenberg, J. Drones as Crime-Fighting Tools in 2020: Legal and Normative Considerations (2018). Harvard Law School National Security Journal. Retrieved May 15, 2018, from http://harvardnsj.org/2018/01/drones-as-crime-fighting-tools-in-2020-legal-and-normative-considerations/.
26. Save The Rhino (n.d.). The use of drones in rhino conservation. Retrieved May 7, 2018, from https://www.savetherhino.org/rhino_info/thorny_issues/the_use_of_drones_in_rhino_conservation.
27. Silvagni, M., Tonoli, A., Zenerino, E., and Chiaberge, M. (2015). Multipurpose UAV for search and rescue operations in mountain avalanche events. Geomatics, Natural Hazards and Risk, 8(1):18-33.
28. The Federal Aviation Administration. Retrieved May 7, 2018, from https://www.faa.gov/news/updates/?newsId=85548.
29. The Sentinel Project. Retrieved May 7, 2018, from http://thesentinelproject.org/.
30. The Statistics Portal. Retrieved May 7, 2018, from https://www.statista.com/statistics/510952/number-of-deaths-from-natural-disasters-globally/.
31. United Nations Office for the Coodination of Humanitarian Affairs (2014). Unmanned Aerial Vehicles in Humanitarian Response. Retrieved May 7, 2018, from https://www.unocha.org/sites/unocha/files/Unmanned%20Aerial%20Vehicles%20in%20Humanitarian%20Response%20OCHA%20July%202014.pdf.
32. Verschoor, C. (2016). Conservation drones for animal monitoring. Master Thesis. Retrieved May 15, 2018, from https://esc.fnwi.uva.nl/thesis/centraal/files/f2134208086.pdf.
33. Waharte, S. and Trigoni, N. (n.d.). "Supporting Search and Rescue Opeartions with UAVs." Retrieved May 7, 2018, from https://www.cs.ox.ac.uk/files/3198/submission_waharte.pdf.
34. West, J. and Bowman, J. (2016). The domestic use of drones: An ethical analysis of surveillance issues. Public Administration Review. Retrieved May 23, 2018 from https://onlinelibrary.wiley.com/doi/abs/10.1111/puar.12506.
35. Whetham, D. (2015). Drones to protect. The International Journal of Human Rights, 19(2):199-210.
36. Zipline. Retrieved May 7, 2018, from http://www.flyzipline.com/

Appendix

Table 1. UAV Classifications

	Maximum Gross Takeoff Weight (lbs)	Normal Operating Altitude (ft)
Small	0-20	< 1200
Medium	21-55	< 3500
Large	< 1320	< 18,000
Larger	> 1320	< 18,000

Table 2. Comparison of Rotary- and Fixed-wing UAVs.

Type	Advantages	Disadvantages	Examples
Rotary-wing	• Vertical takeoff and landing • Ability to hover • Easy and quick to deploy • Easy navigation in closely contained areas • Small landing space needed	• Complex build • Shorter distances • Slower speeds • Expensive repairs and operational costs	Black Hornet CyPhy PARC Saab Skeldar
Fixed-wing	• Simpler, less complex build • Ability to glide • Longer flight times • Less impacted by environment • Cheaper maintenance and operational costs	• Can't remain stationary • Runway/landing strip required • More knowledgeable operators required	Parrot Disco KKMOOM F949 Hubsan H301S Spy Hawk

Dr. A. Nicki Washington is an Associate Professor in the Department of Computer Science and Quantitative Methods at Winthrop University in Rock Hill, SC. From 2006-2015, she was an Associate Professor in the Department of Systems and Computer Science at Howard University. Before joining academia, she was a Senior Member of the Technical Staff with the Aerospace Corporation in Chantilly, VA. She is a 2000 graduate of Johnson C. Smith University, earning a B.S. in computer science. She received her M.S. and Ph.D. from North Carolina State University in 2002 and 2005, respectively, becoming the first African-American woman to receive a Ph.D. in computer science from the university. She is also a 2000 David and Lucille Packard Fellow and 2003 NASA Harriet G. Jenkins Pre-Doctoral Fellow.

Dr. Washington's research interests include computer science education (specifically the use of culturally-responsive pedagogy to increase K-16 student participation and performance) and networking. She is a member of the National Society of Black Engineers (NSBE), Society of Women Engineers (SWE), Institute of Electrical and Electronics Engineers (IEEE), Association for Computing Machinery (ACM), and the American Association for the Advancement of Science (AAAS).