Ubiquitous UAVs

Abel, Chang, Hui, Tu

Professors Browne and Weltman

Engr 183EQ, Dis 1F

August 17, 2018

Contents

Chapter 1

Executive Summary

In recent years, drone technology has seen rapid market growth, driving down cost and improving capabilities. Drones, or more formally unmanned aerial vehicles (UAVs), are suitable to replace status quo in a variety of tasks spread across countless industries. Economic benefits are countless with no end in sight. They have been lauded by police departments (Evangelista, 2017) and fire departments (Branson-Potts, 2018) as life saving. Their uses permeate throughout all sectors in society. Our analysis of UAVs split application into three major areas characterized by their level and range of civilian interaction: surveillance, service and warfare. Surveillance operations are relatively isolated from human social interaction. Service operations directly interact with human society. Warfare operations seek to protect human society. Discussion in each section will examine the numerous cost saving potentials, functionality improvements, and improvements to quality of life. We will also perform cost benefit and ethical analysis, and finally conclude each section with recommended technical and non-technical solutions.

One of the most promising industries for UAV use is in surveillance. As UAV improvements permeate the consumer market, government, academics, and industry are able to justify purchases. Recent models are built on platforms that allow easy connection with numerous sensors. Using high definition (HD) video and photography cameras, UAVs are poised to take over in numerous applications. The small size and vertical flight capabilities allow UAVs to navigate to places that are difficult to reach. Remote and autonomous operation makes it now practical to perform actions that would have been otherwise tedious, such as photogrammetry. Machine learning and cloud processing supersedes many human abilities. For example, UAVs replace manned helicopters that place firefighters at risk in autonomous fire monitoring. Lack of required intervention means UAVs can fly in predetermined paths at regular intervals, providing semi real-time updates to firefights at little additional cost (Merino, 2010). They represent improvements in cost, functionality, and security.

Another application of UAVs in surveillance is in the field of ecological and geological mapping. A day in the job involves professionals flying close to natural habitats in order to assess the state of an environment or biome. This is both prohibitive, since not all locations that require mapping are easily accessed by people with cameras, as well as disruptive, in the case of professionals approaching animals and wildlife. UAVs are able to circumvent both these problems by nature of their technology. Compact designs and quiet flight systems render approaching any and all ecosystems a trivial matter. As stated, the quality of data recorded by UAVs is not inferior to that of human professionals. Only in very niche cases, where specialized tests were required, would human workers be a necessity when compared to UAVs.

In addition to mapping ecosystems, UAVs would be very applicable in the field of population mapping. Pollution mapping similarly involves traveling to various locations in order to poll information, take pictures, and record data. The additional hurdle that must be approached when dealing with pollution mapping is that oftentimes, professionals are put locales with toxic and potentially carcinogenic conditions. The costs associated with mitigating the biological dangers of the job are high, and the introduction of UAV technology would be able to reduce a bulk of the cost by a large margin. Instead of having to purchase expensive safety equipment for the on site personnel, drones would merely have to be examined for wear and tear before they could go out and continue to collect data.

One last application where UAV technology would be a great boon is in the field of infrastructure surveillance. Bridges, buildings, and other constructions must be often examined for structural defects and safeguarded against factors that may compromise safety. This frequent examination is very costly, as navigating around a building requires several approaches and a myriad of equipment and techniques. In addition, this line of work is not without its dangers. It is not unheard of for human professionals to plummet from the sky when scaling a tall building, or fall into the waters when examining bridge stability. UAVs would be able to safely execute and carry out a large majority of jobs that previously would endanger lives.

As apparent through the discussion of the applications of UAVs to the surveillance sector, drones can be a great boon by taking away the risk to lives. Many surveillance jobs today require actual humans to carry equipment in order to attain data, take pictures, or examine conditions.

Ethically, this is a very desirable thing. There is no harm done by taking human lives out of danger and replacing them with machinery. An analysis using Utilitarianism would lead to the conclusion that it is very ethically sound for drones to begin to work in the field. There are, however, some concerns to be addressed. Since surveillance inherently requires the storage of data, there must be policies in place to prevent the unethical storage of data.

The invasion of privacy is a large consideration when discussing unmanned vehicles with the capability to record footage and take pictures. There are a few solutions that we recommend that would preserve the privacy of people. Firstly, it is crucial that all UAVs have a way to be identified, namely through means of a digital signature, so that culpability can be assigned in any case. Any drone without a registered digital signature is suspect and will be immediately suspect in any incident. Secondly, the data taken by drones lawfully must be deleted or publicly released following a certain period of time. This system of peer review is to ensure that no abuses, intentional or unintentional, be made by the lawful use of drones.

Another industry with very promising prospects for the implementation of UAV technology is the service industry. Drones are more robust and possess better physical capabilities than human workers, making them prime candidates for a field where performance is vital. One specific application of UAV in the service industry is parcel delivery. Delivery has always been bottlenecked by human inefficiencies. The domestication of horses, the introduction of automobiles, and the advent of GPS all served to correct flaws that humans had in order to expedite getting items from point A to point B. UAVs are superior to human workers in this job, being faster, less prone to mistakes, and immune to fatigue. It stands that drone efficiency would lead to unprecedented growth and profits for the delivery business.

Yet another service application of UAVs is in the field of journalism. Live reporting has always been dangerous because of the necessity of reporters to be on site, often times putting their lives at risk in order to provide coverage on a story. Violent neighborhoods and unsafe weather conditions are normal occupational hazards. In addition, the costs associated with journalism are not to be underestimated. Rushing to a site in order to provide live coverage incurs the costs of on call staff as well as fast transportation. UAVs, with their previously discussed merits, are able to seamlessly take the place of live coverage reporters. Machinery would be at risk instead of actual lives, and many costs associated with the transport of staff are no longer necessary. A final useful application of UAV technology in the service sector can be found in the healthcare industry. Drones can be used in the healthcare industry for many purposes that human workers are unable to fulfil. For example, it is possible to deliver an emergency dosage of medicine to a patient in an extraordinary short amount of time using UAVs. Whereas conventional procedure would require the dispatch of on call staff and an ambulance that would have to navigate through traffic, a drone would be able to fly straight to the location of the patient. In addition, drones would also be able to actively monitor patients that are at risk. Instead of having a nurse actively monitoring a patient, or relying on the patient to call for help in the case of an emergency, drones are able to dynamically keep track of multiple patients and route all the footage to something akin to a surveillance room.

The ethical and societal implications in using drones for the service industry are multifaceted, but perhaps the most important point is that drones are so efficient in replacing service workers that jobs would be sizably reduced. If one analyzes this using Utilitarianism however, it is apparent that the greater good is done by introducing UAVs into the service industry. People may lose their current jobs, however humans lives at risk would be decreased and the economic growth of the respective sectors would increase. In addition, additional jobs would be created for the maintenance of drones, offsetting the reduction in jobs where UAVs have displaced workers.

One final sector in which UAV technology would offer great benefits is in warfare. UAVs offer unparalleled benefits for the purposes of both scouting and combat because of their machine characteristics. The prime concern for war is the saving of as many lives as possible. In a sense, there is an armed conflict, one that may require lives, that two sides participate in to further their agenda of the greatest good for their people. Drones would serve to reduce bloodshed during war by partially replacing soldiers. In addition, drones would perhaps serve a better role than conventional soldiers because of their ability to fly stealthily and their resilience to human conditions such as hunger and fatigue. The reduction of casualties is paramount in any consideration of warfare, and the application of UAVs is promising in that regard.

Regarding the ethical and societal considerations, of using drones for warfare, the topic is very controversial. Many of the controversial elements originate because of stigmas. Machines having guns will not results in more deaths or machines running amok. Instead, that robot that was lost in the line of battle served as a replacement for someones loved one. Another concern of having drones in the line of combat is their ability to be exploited. Machines may fall prey to hacking and dismantling after they are captured, which may provide intelligence to opposing forces. This point is debatable, given the fact that similar arguments can be made for humans, that they are prone to torture. There is simply no comparison. In order to arrive at a conclusion that is not fraught with opinion, it is important to apply ethical analysis.

By using Utilitarianism, it becomes clear that using UAVs for warfare, if the technology permits, is actually the ethical course of action. In terms of costs and benefits, the costs of having to use UAVs would mean that further research would have to be done and money would have to be sunk into development. The point can be made that the same funding would have gone to training human soldiers anyways. The benefits of using UAVs for combat however, strictly outweigh the opposing factors. Human lives can be saved, the lives of many soldiers who must sacrifice themselves in the line of combat. One limitation of Utilitarianism is that it cannot quantify human life. That being said, it is an astoundingly great development that our society today is able to put money into machinery that may be able to take priceless lives outside of harms reach. Although UAVs have a great inherent capability to benefit society because of their technological application, there is always the concern for abuse of new technologies. UAV engineers, governments, and companies that decide to employ drones must always be diligent to enforce policies and enact legislation to limit the abuses that can occur. There is great potential in the future for drones to supplement, improve, and transform a wide variety of industries, ranging from the service and surveillance to even the military, if proper ethical considerations are observed. We hope that this paper serves as a launching point to familiarize the reader with UAVs, and to provide recommendations so that they know where to go next.

Chapter 2

Introduction

The methodology used to create this work was twofold: we wanted to collaborate in order to write about topics we thought were both interesting as well as relevant in todays world. We first got together in order to brainstorm what topics we were interested in covering for our report. The total body of information regarding UAVs is vast, perhaps too vast to fully cover in a single work. Thus, our first task was to draft a list of topics we felt passionate about. We felt that writing about topics we did not feel invested in would yield a work that was perhaps informative, but not moving nor persuasive. After we were able to identify the topics that were intriguing to us, we moved on to identifying the relevance of our list of topics. While there is the pitfall of writing that is too numbers heavy, too informative, and lacking compelling themes, there is also the trap of subject matter that is intriguing but has no relevance. As an engineer, it is vital that we busy ourselves with work that is both interesting and compelling, yet at the same time is able to distribute positive change into the lives of those around us. After we were able to identify the topics and subject matter that we were to write on, the rest of the work was simply that: work to produce the final version of our report. We would convene as a group at least once weekly in order to share ideas and update each other on the progress we made individually. Doing this allowed us to understand the topic at large and what each individual was working on, while also allowing for each of us to become focused on the individual topics and nuances that we assigned ourselves. The finer details of who did what portions of this report is available in the form of a Responsibility Assignment Matrix that is presented below in Table 1. We will briefly highlight the contributions of the individuals in the remainder of this introduction.

Table 1: RAM Chart detailing the distribution of responsibilities of this paper.

	Jordan Abel	**Jonathan Chang**	**Wing Hui**	**Amy Tu**
Executive Summary	R	I, D	P	I, D
Introduction	R, I	I, D	P, I, D	I, D
Problem Statement	R	R, I, D	P	I, D
Ethical Frameworks	R	R, I, D	P	I, D
Surveillance				
Fire Monitoring		P	R	
Ecological and Geological Mapping		P	R	
Pollution Mappings		P	R	
Infrastructure		P	R	
Ethical Discussion	I, D	P, I, D	I, D	R, I, D
Recommendations		P		R
Service				
Parcel Delivery	R		P	
Journalism	R			P
Healthcare		R		P
Ethical Discussion	D, I	R,I,D	I,D	P,I,D
Recommendations	P			R
Warfare				
Scouting			R	P
Combat			R	P
Ethical Discussion	P, I, D	R,I,D	I,D	I,D
Recommendations	P			R
Conclusion	P, I, D	R,I,D	I,D	I,D
References		R		P
Final Proofreading				P

Jordan Abel was most interested in the solutions to the various problems presented by the introduction of UAV technology into society. Thus, he was responsible for the ethical discussion regarding UAVs in warfare applications, as well as the recommendations for UAVs in both service applications as well as warfare applications. In addition, he was primarily responsible for writing the conclusion to this report that outlines the implications and outcomes of UAVs.

Jonathan Chang had the greatest interest in the surveillance applications of UAV technology. Thus he was responsible for the entirety of the surveillance section of this report, from the various useful applications that UAVs have in field, to the ethical discussion of UAV use in surveillance as well as the associated recommendations that stem for such discussion.

Wing Hui felt that the entire concept of UAV technology was very novel and intriguing, and thus he was occupied with learning as much about the field as he could. He was responsible for writing the executive summary of this report, as well as the introduction, problem statement, and introduction to ethical frameworks. In addition, he contributed to the service portion of UAV applications by writing about parcel delivery.

Amy Tu expressed interest in various social applications of UAV usage, and thus she was responsible for writing the sections regarding journalism, healthcare, scouting, and combat, as well as some associated ethical discussion and corresponding recommendations. In addition, she was primarily responsible for the formatting of the references cited and the final proofreading of the paper.

Chapter 3

Problem Statement

UAVs are uniquely suitable for a large variety of tasks. They are usually remotely or autonomously controlled, and require no on-board pilot to function, allowing for a number of processes traditionally manually rendered to be streamlined and automated. Therefore, market prospects for UAVs have grown dramatically in recent history. The value of the UAV industry in the United States was worth around $40 million in 2012, and the industry has grown to be worth upwards of $1 billion by 2017 (Forbes, 2018). The implementations for UAV technology range from service oriented tasks, such as parcel delivery and health care, to surveillance jobs, such as photogrammetry and fire monitoring, and even to applications in warfare, such as combat and scouting. While the future for UAV looks bright, there is also a darker side: the potential for criminal and opportunistic abuse. Improper applications are often similar, and counterfactual to proper uses. UAVs, capable of crystal-clear camera recordings and large carrying capacities, are being used for stalking and drug smuggling (Tucker, 2018). This massive potential for crime demands action in order to allow for UAV technology to continue to grow and benefit the private and public sectors. Legislative measures must regulate the their use. Preventative measures, such as mandatory registration of all UAVs and strict data collection policies, as well as active measures, such as constant location tracking of UAVs and police supervision over public and private disturbances, are required in order to keep the technology in check. The potential for UAVs to benefit society is great and is growing daily, but a diligent eye must be kept in order to limit the dangers of under regulation and technological abuse.

Chapter 4

Ethical Frameworks

Ethical frameworks are the means by which professionals, engineers in our case, can scrutinize situations and actions and determine if the course taken by individuals was ethical and morally sound. Ethical frameworks represent a methodology of thinking, pioneered by the thinkers of the past, that is accepted to be able to be applied to a variety of situations in order to determine the salient points that are worth discussion with regards to ethics. There are a variety of ethical frameworks that are useful, each with their own merits. In our report, we have chosen three frameworks that we feel are most suited for the analysis of UAV technology: Virtue ethics, Kantianism, and utilitarianism. We will provide normative ethical analysis, with suggestions of how people act in the situations here forth presented. We feel that given the nature of UAV technology, a technology that offers many useful applications within fields that already exist, it is paramount that we analyze the actions people should and should not take when using the technology.

Virtue ethics is an ethical framework that scrutinizes the characteristics of the actor. It examines virtues, thought to be a set of fixed properties that are ideal. Aristotle formulated virtues as the middle ground between two extremes. For example, healthy altruism might situate between miserliness and self-sacrifice. The Greeks had four canonical cardinal virtues: wisdom, justice, moderation, and justice. However, each subsequent culture revised this set to fit their own ideals, sometimes including religious ideals of hope, faith, and charity. Virtue ethics are sometimes characterized as vague and arbitrary. We will not use any specific set of virtues, but rather call upon our own experiences and analyze in the context of modern culture.

Kantianism is a deontological ethical framework concerned with actions rather than the individuals. Kant called typical actions driven by external causes the hypothetical imperative, such that they are performed only if a goal is desired. Moral actions must be driven in and of itself. They are categorical imperatives. Kant gives two formulations, the universality principle and reciprocity principle, both of which are necessary for morally right actions. The universality principle states act only on that maxim which you can at the same time will that it should become a universal law (Poel and Royakkers, 2018). In essence, a righteous action must not contradict societal order if everyone followed it. The reciprocity principle states act as to treat humanity, whether in your own person or in that of any other, in every case as an end, never as a means only (Poel and Royakkers, 2018). Therefore, other people should never be treated as means to some external goal, only ends in themselves. Actions that take advantage of people, that use them for goals that do not primarily benefit them, are unethical. Following reciprocity, Kant also argued that people should not be denied relevant facts to give informed consent. People without autonomy are coerced; therefore, autonomy must be desirable. Critics argue that Kantian rules are rigid, and that they lead to odd consequences when duties conflict. We try our best to provide fair ethical analysis, and use Kantianism to demonstrate bottom-line status of affected minorities.

Utilitarianism is a framework under consequentialism, ethical theories concerned with the outcomes of actions. Utilitarianism was formulated by Jeremy Bentham with the utility principle, which states that a morally righteous action should cause the greatest happiness for the greatest number of people. That is, each consequence of an action is assigned a negative to positive number based on the amount of pain or pleasure, respectively, inflicted on people. The totality of all consequences are summed up with a hedonist calculus, wherein the positivity of the result indicates the moral value of the action. One should strive to achieve actions that maximize utility. In Benthams original formulation, only direct consequences of actions are counted. Critics against utilitarianism note that subjective experiences are incommensurable, and further that there are different types of pleasure and pain. John Stuart Mills, a later philosopher, attempted to refine the theory by placing relative weights on different kinds of pleasure, such that higher orders of pleasure are more valuable than base animalistic pleasures. However, this invites criticism that the ordering is ethnocentric. We apply utilitarianism to elucidate facts about societal benefits without being bogged down with meta-ethics.

Recent neuroscience has shown that Kantianism and utilitarianism may be complementary and target different responses in the brain. Kantianism triggers the amygdala, responsible for emotive process, to incur instincts to protect the minority. Utilitarianism triggers the prefrontal cortex, responsible for deliberative reasoning, to more rationally consider a cost-benefit analysis.

Joshua Greenes dual process theory is derived from fMRI scans of subjects prompted by variants of the trolley problem. It is not without criticism, but provides recent insight into ethical theory (Saalfield, 2012). With this in mind, it is beneficial for us to use multiple frameworks to obtain a more complete picture.

Chapter 5

Surveillance

5.1 Background and Applications

The following problems are deemed to be isolated from society, in that drone sensing occurs in a highly specific context removed from the general populace. The chosen problems are fire monitoring, ecological, pollution and geological mapping, and infrastructure and construction. Although the uses are somewhat different in each field, they share much of the same underlying premises, hence the technological and ethical issues have much in common. UAV uses in this section are heavily dependent on photogrammetry, mapping various features into digital surface models (DSM), orthophotos, and 3D models. These models are then analyzed by various software, usually on a cloud, and information extracted and targeted to different interests. A discussion of relevant technology preceding ethical analysis clarifies the problems, since ethics must be subject to physical facts – it does not exist in a vacuum. UAVs, in these uses, have the ability to provide enormous value in both cost savings and safety, such that they can no longer be ignored. Despite so, privacy advocates are against their use. For example, ACLU has tried to block various CA fire departments from using drones with the privacy argument (Branson-Potts, 2018). We argue that their fears are misguided for isolated problems, and we provide justification in our ethical recommendation.

5.1.1 Fire Monitoring

Annual wildfires have significant, wide-ranging impacts. They damage the economy, threatening property, infrastructure, and tourism. They endanger local wildlife and ecosystems, destroy vegetation to enable soil erosion, flooding, and damage the water downstream. Soil eroded over time may uncover archaeological artifacts, which are also at risk. The smoke also causes respiratory ailments at a distance. In fact, the U.S. Forestry Service has estimated that 6.3 billion tons of biomass is burned each year, about 3% to 5%, or 7 million acres, which occurs in the United States (Herring, 1998). Some of this is deliberately allowed, such as to manage coastal sagebrush ecosystems, but it costs the U.S. billions annually regardless. The economic cost of California wildfires in 2017 alone exceeded $85 billion. Cal Fires estimated several fires had caused 5,700 buildings to burn down, and over 100,000 people to evacuate (Lada, 2017). This is just a small fraction of the 51,000 fires reported by the National Interagency Fire Center that year (Lada, 2017). While its true that 2017 held a record in the amount spent in fire suppression, over $2.4 billion, the 10 year average is around $1.1 billion, still a significant number (Lada, 2017).

Fire monitoring is instrumental in developing an effective containment strategy. The shape and position of the fire front, the spread rate, and maximum height of flames are important information for management. Previous efforts to monitor relied on human visuals from helicopters or surveyance towers, or satellites. However, smoke often blocked flames and impaired human visuals. Compounded human error made fire localization difficult, a discrepancy that might, for example, waste water. This also posed some danger to the experts on field (Merino, 2010). Satellites have also been in use since 1999, such as NASAs Earth Observing Terra System satellite, which hosts the Moderate-Resolution Imaging Spectroradiometer (MODIS) instrument. The MODIS has a 1 km resolution, so it can only detect the largest 25% of fires worldwide that are responsible for most biomass burned. It turns out that fire intensity is proportional to brightness, which is visible from satellite (Herring, 1998). While this technology is an improvement over previous methods, the resolution is also a weakness.

UAVs have numerous advantages in fire monitoring. They are safer and less expensive than the manpower, helicopters, and fuel involved in human visuals; they are also more precise than satellite imaging. During the 2017 Skirball fire in Los Angeles, the LAFD employed 2 DJI Matrice 100s (Branson-Potts, 2018), at under $3,300 each (DJI website), to provide real-time situational awareness at a birds eye perspective. One was equipped with an HD camera to survey burn area, and the other had a near-infrared (NIR) camera to assess hot spots (Branson-Potts, 2018). The UAVs were able to fly much closer to ground, and had significant resolution advantages. Compared to satellites, multiple drones can compare complementary views of larger fires. Their free mobility allows autonomous flight to various predetermined vantage points, as well as waypoints for recharging. They can graph real-time parameters and wirelessly integrate visuals with geographical information systems (GIS). Moreover, deep learning aids in predicting fire path using stabilized images and fire contours as predictors (Merino, 2010). Preventative forest fire discovery could use multiple low-cost drones and image enhancement with a vegetation color index adapted to detect tonalities in fire and smoke. Reporting GPS coordinates would be cheaper than sending video. Preliminary tests showed 96.82% test set accuracy using database images (Cruz, 2016).

5.1.2 Ecological and Geological Mapping

Wildlife conservation requires data collection of population dynamics without disturbing the natural site. Accurate population counts allows informed management decisions. Invasive and endangered species detection is especially useful (Hodgson, 2018). However, taking high resolution photos and observing animals up close is very difficult. Light aircraft crashes are the number one killer of conservation biologists. Out of 91 scientists recorded to have died on a mission, 60 were due to crashes (Averett, 2014). Traditional counting, whether from ground or plane, is an intensive, error prone exercise. Scientists had to fly planes close, which might cause disturbance (Hodgson, 2018). In one study, manual counts of tern birds took between 9.5 to 16.75 hours. A UAV achieved this same task in 5 to 7 minutes (Hodgson, 2018) using photos and a learning algorithm to detect contrasts. Figure 1 below shows a typical scene where a conservationist might hide on a cliff to count birds.

Figure 1: Birds on a rock outcrop required manual counting by conservationists (Bryce, 2015).

This underlines the significant advantages of drones over traditional conservation methods. Their small size offers greater vantage while minimizing disturbance. Surveying hard-to-reach places and populations becomes possible with vertical flight capabilities, for example in arctic caves or dense tropical forests. They can continuously process images, or save them for post-processing, which reduces variance compared to on-site counting (Hodgson, 2016). Therefore, UAVs are capable of extremely fine spatial and temporal data collection (Hodgson, 2018), picking out details that are hard to see. Autonomous recharging with waystations allows remote missions. For example, they were employed to make rapid population estimates of the Tristan albatross in a remote island, despite low nest densities. Learning algorithms are sophisticated enough to distinguish fine differences in species and different objects. One study planted fake birds among a population, and UAVs were able to identify the real ones with 43% to 96% more accuracy compared to ground counting (Hodgson, 2018). Digital photos are geo-referenced with GPS to construct a more complete narrative. Recent advances allow UAVs to avoid crashing into other birds, catch objects midair, and perch on trees, effectively blending into a flock of birds (Averett, 2014).

These properties of safety, efficiency, low cost, and stealth make certain activities feasible that were previously risky. UAVs could, for instance, safely monitor, take pictures of, geo-reference, and wirelessly send legally admissive evidence of poachers and illegal loggers caught in the act (Averett, 2014), capture car license plates entering a preservation site to enforce prosecution (Drone Powered Solutions, 2017), and monitor breeding success of canopy birds or elephants (Hodgson, 2016), which may be time intensive. Using UAVs for geological surveys offer many similar advantages. The surveys are used to identify subsurface features, natural hazards that potentially threaten society, natural resources and impacts of land use (USGS.gov). Certain geological features are difficult to navigate or dangerous, such as overhanging rock outcrops, caves, gas-rich or active volcanic areas (Jordan, 2015). Highly sloped mountainous areas can be time consuming to navigate (Piras, 2016). Photogrammetry, using photos to measure distances and geographical positions, require numerous precisely leveled shots, often at inaccessible vantages for accurate post-processing and computation. Reliable photograph allows much of this process to be automated, greatly reducing cost and safety risks. Traditionally, both ground surveys and satellite imaging are limited in resolution and precision, and does not investigate all properties of the terrain. For example, water content is available through photogrammetry analysis, but difficult to estimate manually (Piras, 2016).

In addition to acquiring data more rapidly and inexpensively (Piras, 2016), a number of additional advantages are uniquely available to UAVs. Their ability to automate continuous parametrized photos allow aerial surveys of real-time mapping, which is particularly useful during and after disasters, such as flooding or earthquakes. Surveying sediments and rock formation to generate paleoseismic models can supplement post-earthquake land change monitoring to calculate seismic hazard. The variety of simultaneous sensing generate model overlays (Jordan, 2015). Using both HD cameras and NIR cameras to perform photogrammetry, digital surface models (DSM), digital terrain models (DTM), and orthophotos can be generated automatically (Piras, 2016). This could allow simultaneous topological and bathymetric (top and bottom) mapping of lakes. Vertical flight and small sizes allow 3D mapping in tight places. It could be flown inside caves for karst limestone research (Jordan, 2015), or used to find inaccessible areas in glacial valleys (Piras, 2016). Other similar applications include territorial analysis, landslide monitoring, deformation analysis, and monitoring geothermal environments (Piras, 2016). In fact, drones have been used to observe volcanic vents from directly over the volcanic crater (Jordan, 2015), which would not have been possible otherwise due to safety risks. In one use case, small UAVs performed stockpile management and surveillance of mining installations. Geologists in Indonesia used 3 DJI Phantom Professional 3 drones, less than $1,500 retail, with built in 12 megapixel cameras with geotagging. The drones flew at an 80 to 100 meter altitude range at various angles, took photos every 5 seconds and recorded the altitude. The photos were stitched together using photogrammetry software to map geological outcrops. These low-cost, but high resolution, pit and bench mappings were used to create photo-realistic 3D models of the mineshafts. Continuous mapping provided real-time updates and stopped illegal miners (Szentpeteril, 2016).

5.1.3 Pollution Mapping

The extent of the air pollutant impact is difficult to measure. The health ailments they cause stochastically manifest due to genetic and environmental factors that remain unclear. However, the effects are tangible. Pollution has driven evolution in some plants and animals, and externally altered the appearance of others. Peppered moth had evolved to turn black to camouflage into a dirty environment near industrial cities (Feeney, 2015). Likewise, sea snakes have evolved from their trademark black and white stripes to an all black skin near cities, because the pigment helps rid trace arsenic and zinc (Bittel, 2017). DNA sequencing of fish like the Atlantic killfish has shown that they have adapted to pollution a thousand times above legal levels within the last 50 years (Le Page, 2016). Scientists have learned they could identify pollution levels by observing the darkness in the naturally white horned lark feathers due to accumulated soot (Gibbens, 2017). It is clear that the complex mixture of liquids and solids that makes up air pollutants, or particulate matter, assumes colors that can be seen with the naked eye. Aydogan Ozcan, engineering professor at UCLA, says some particulate matters are carcinogenic when breathed in (Choi, 2017). Particulate sampling informs policies that set standards to correct for air pollution. Previous solutions used beta attenuation monitors, bulky machines that require expert operators. They weigh as much as 30 kilograms, cost between $50,000 to $100,000, and require regular weekly maintenance. Portable particle counters cost between $2,000 to $8,000, but only sample 2-3 liters of air per minute, ineffective for very low or high concentrations that particulate matter often are. Neither provide images for analysis (Choi, 2017). Urban areas can benefit from crowdsensing, or installing these cheaper counters on a variety of objects. While this is effective, it is still expensive, and unsuitable for more rural areas with less operating density (Alvear, 2017).

UAVs might solve all of these concerns with superior mobility for imaging needs, so that less monitors are necessary. They are fitted with inexpensive parts like the Raspberry Pi processor, and Grove sensors (Alvear, 2017). They interact wirelessly with the cloud to use deep learning for image recognition. Vertical flight capability makes it possible construct 3D mapping, while autonomous operation allows sampling in toxic, hazardous environments, like plant smoke stacks, both impossible with human ground-based operators (Choi, 2017). Ozcans team developed a mobile imaging device they call c-Air that weighs only 600 grams and sample up to 13 liters per minute. It generates microscopic images with up to 93% sizing accuracy. The device is controllable with a smartphone, and mounts on medium-sized drones, such as the DJI Flame Wheel, which retails under $400. Images are captured at 1.7 micron resolution, smaller than a human hair, and the particulates identified using cloud computing. The UAV was able to map pollution around Los Angeles to find that the LAX airport impacts air quality up to 47 kilometers away. Across the Pacific, Chinese UAVs programmed to detect 8 specific pollutants flew around a city 100 meters above ground. They built a real-time geographic pollutant map in 30 minutes and found the biggest impact sources. These UAVs are now being used by Dongguan law enforcement to monitor plants and factories (Choi, 2017). With UAVs, it is now possible to sample particulate matter at higher detail and efficiency, lower cost, and detect sources and changes in pollution with image mapping, which was previously impossible.

5.1.4 Infrastructure

Construction projects require numerous teams – architects, engineers, planners, builders, investors, lawyers, and security personnel – to be well coordinated. Slight mistakes or deviations from the plan could quickly turn into millions in loss, or loss of lives of builders or clients. Therefore, construction projects never truly end when constructions end; rather, a protracted maintenance and upkeep help catch problems in their formation. Failure may be catastrophic. In August, 2007, a span of Interstate 35, the busiest bridge in Minnesota, snapped and plunged into the Mississippi River, killing 13 and injuring 145 more. Inspection had shown that it was an engineering failure, so the state spend $2.5 billion over the following decade repairing hundreds of bridges with more stringent design. By 2017, repairs were complete, but expensive maintenance caused Minnesota to look into process improvements. Traditional bridge inspection required either engineers to lower themselves below the bridge on ropes, or the use of snoopers, heavy duty trucks with extending arms. However, the latter can cost around $1 million each. Lane closures are a public inconvenience and safety hazard, since it increases crashes. Around the United States, the American Road and Transportation Builders Association has estimated that 55,000 bridges are in need of repair (Bliss, 2018). Similarly to bridges, road and rail infrastructure are a huge drain in public resources. In this aspect, Asian Pacific economies, like China or Indonesia, are no longer able to keep up with their growth (Drone Powered Solutions, 2017). Figure 2 below shows a snooper occupying a small section of a bridge in Minnesota, requiring an entire lane to be closed. The entire length of a bridge needs to be examined in this manner. UAVs scan the entire length of a bridge without occupying road space.

Figure 2: Snooper observes a small section requires lane closure (Mn DOT Research, 2017).

UAVs are useful in all stages of construction. Standardized drone technology implementation with Building Information Modelling (BIM) methodology significantly improves construction, post-construction, and maintenance phases. Therefore, the U.S. government had spent $35 million to find out how UAVs could intelligently monitor and inspect infrastructure (Drone Powered Solutions, 2017). In Minnesota, specifically, UAVs with mounted cameras were able to scan entire lengths of bridges, getting up close to find cracks or fissures. They snap thousands of high definition photos to be stitched together into 3D models. Over time, these models could be played back by engineers to find a structures rate of deterioration. Certain UAV models have cameras that tilt upwards to see the undersides of bridges. Other UAVs are able to crawl along high abutments or narrow holes. These operations occur alongside normal road operation without closure, greatly decreasing costs in the long run (Bliss, 2018).

These uses apply to any kind of development project, not just bridges or infrastructure. Drone Powered Solutions is a team of PricewaterhouseCoopers Poland dedicated to supporting industrial clients by maximizing UAV potential. The team have found that UAV-based monitoring is up to 20 times faster than ground-based surveying, and provide a high level of supervision to track progress and quality through every stage of a development project. UAVs were used to assess initial planning, and impact to the environment and nearby parties, to pre-verify site risks and conditions before building. They traversed flight paths at regular intervals to take photos packaged into photogrammetry products. These included digital surface models (DSM), orthophotos, and high-definition 3D models. This enabled regular reports of work status, adherence to plan, and early identification of risks and safety issues. The models assisted in placement of trench protection. Off-hours monitoring provided detection and prevention of trespassing, improving safety. These features and others helped UAV-monitored construction sites decrease life-threatening accidents by 91%, and serve as credible documentation for legal proceedings. In one project supervised by the Drone Powered Solutions team, the investors saved $2.94 million in litigation costs due to evidence from UAV monitoring. Improvements that are currently being researched would use augmented or virtual reality to allow designers, architects, or engineers to access the construction project in real time, with material information, warnings, assembly and logistics information projected onto the screen. UAVs learn to fly autonomously through deep learning, and recognize suspicious activities. All collected data are uploaded to the cloud in near real time to allow managers or investors to monitor progress and delays. Aerial construction might also be possible: Scientists at ETH Zurich under professor Raffaello DAndrea built rope bridges and ventilation shafts with swarms of UAVs faster than humans. These are both dangerous activities (Drone Powered Solutions, 2017).

There are other use cases where frequent monitoring is crucial, yet difficult. UAV monitoring could help in maintenance of high voltage pylons, telecommunication masts, and wind turbines. Cloud image processing and deep learning enable previously unattainable precision. Infrared cameras detect overheating from load imbalance, wrong connections, and powerline corrosion, all without risk of injury. Traditional inventory management require workers to make ground-counts in areas with moving forklifts, trucks, and other hazards. It is labor intensive and prone to mistakes. UAVs use cameras to scan barcodes, sensors to detect RFID, and long-range, low-powered (LoRa) wifi to achieve stocktaking autonomously. It can also simultaneously detect container defects in the railyard. Real-time collision detection and avoidance is possible (Drone Powered Solutions, 2017).

More futuristic, long-term uses in autonomous infrastructure repair are being researched. In 2015, a team from the University of Leeds, U.K., won a $6.4 million grant to develop autonomous repair UAVs, with the idea that monitoring and identification of smaller cracks before they develop into manholes would make them less expensive to repair. They planned three kinds of drones: ones that repair infrastructure above ground, such as street lights; ones that patch up cracks in the pavement; and ones that drop into pipework beneath streets and perform metering and reporting (Sorrel, 2015). It is unlikely that this project would be successful in the near term; however, long term possibilities are numerous.

5.2 Ethical and Societal Considerations

5.2.1 Energy Efficiency

Energy efficiency is perhaps of utmost importance since it directly influences every use case in cost and functionality. Failure to justify this limitation invalidates UAV usefulness. This is especially true due to the light weight of rotor UAVs, making it susceptible to dynamic weather conditions, high winds and harsh weather in high altitudes. The use cases involve long trips on limited battery (Tseng, 2017). UAVs need to monitor wilderness on extended time and take hundreds of photos for photogrammetry. The advantages of autonomous operation are limited if personnel are required to be on standby for recharging, so UAVs need systems to calculate battery life and automatically recharge. This can be achieved with a white box model of power consumption, such that each physical factor is sensed and measured, but the complex sensing and calculations required can be unwieldy and spends the battery. More often a black box model of statistical regression trained on prior conditions is employed. Studies have shown that the black box model is sufficient for estimating battery life (Tseng, 2017). This is significant since high winds have potential to greatly reduce battery life.

Even under ideal conditions, our current battery capacity supports a 4 kilometer range. The Department of Energy target for 2022 is an 8 kilometer range per charge. Most applications require UAVs to fly round trip, leaving a safety buffer. Sensors and actuators, such as HD cameras, contribute additional load. Limited range requiring frequent recharging increase energy costs. For parcel delivery, these costs might be questionable compared to diesel truck deliveries (Stolaroff, 2018); however, degrees of freedom and wider availability of electricity makes UAVs irreplaceable. The range limits usefulness of UAVs applications requiring large coverage, such as preemptive fire detection.

Several recharging formats have been proposed, with the most popular being distributed waypoints either in fixed locations or through mobile trucks. 10 of these waypoints are necessary to service an area the size of the city of Los Angeles with minimal noise pollution and privacy effects for small parcel delivery (Lohn, 2017), but also to monitor pollution or any infrastructure. Limited landing accuracy and diverse environmental conditions makes contact-based charging impractical, so inductive wireless transmission is preferred (Tseng, 2017). Strongly coupled magnetic resonant induction allows power transmission for up to 2 meters. Drones may use GPS and 2D Light Detection and Ranging (LIDAR) camera sensors to coordinate position relative to charging stations (Junaid, 2017), while laser rangefinders and encoders may allow charge station rovers to navigate towards landed UAVs. Charging stations may be powered with solar panels (Tseng, 2017). A study using commercially available XKT-510 IC wireless charging module demonstrated 75% wireless power transfer (WPT) in about an hour, with 3-15 variable VDC and an operating temperature range of -55 to 125. A takeoff command is sent when battery status approaches 100%. The study used open source image processing engine Open CV to perform HSV color filtering, morphological operations, Gaussian blur, and then a Hough circle transform to detect a red circle on the launchpad (Junaid, 2017).

Energy efficiency enables UAVs to be used for a variety of ethically relevant applications. As a new technology, it has a fast iteration cycle, and battery life is one feature that is slated to increase. Governmental agencies may aid in this process to push for a greener future, depending on the administration. For monitoring tasks, however, this primarily improves upon functionality, since the alternatives of satellite and helicopters are already functionally and cost-wise incomparable (Branson-Potts, 2018). Satellites are the most expensive upfront; therefore, they have the slowest iteration cycle. They are limited by bandwidth, resolution and accuracy (Piras, 2016) due to their rarity and distance. Manned helicopters require much more fuel due to the size, are subject to human error, and also pose human safety risks (Merino, 2010). These drawbacks accentuate UAV technology as currently the most efficient for this use case. Electric rechargeability improves portability and decreases cost variance, especially when supplemented with solar panels. This potentially reduces carbon footprint and encourages renewable energy dependence.

5.2.2 UAV Vision

Photogrammetry constructs models by taking photos at different locations and stitching them together with software. Traditionally, topographical maps drawn on paper required considerable practice to both produce and interpret. Geographical surveying is time consuming and subject to human error. Although it is still common to manually extract elevation points along man-made features, and measure reference levels, autonomous image correlation using LIDAR and interferometric synthetic aperture radar (IFSAR) produces the most accurate and cost effective high-resolution elevation maps for large areas. The manual input is relatively minimal, since drones are capable of autonomously taking tens of thousands of photos for digital surface models, orthophotos, and 3D models (Schuckman, 2018). UAVs equipped with multiple sensors can capture an array of data simultaneously and wirelessly send them to the cloud for computing digital terrain models (DTM), which measures elevation without vegetation or buildings relative to a reference height, and digital surface models (DSM), which includes all features above ground. The former is superior for engineering analysis (Schuckman, 2018), while the latter is more visually intuitive. Orthophotos, which corrects central perspective projection, removing perspective or camera tilt to preserve the correct distance at every point, are made by taking photos over a grid of locations at constant height (Tate, 1998). These models are regularly maintained by the government, or companies like Microsoft, for use by scientists or engineers using geographical information systems (GIS) (Schuckman, 2018). These technologies are expensive and often infeasible when performed manually, but autonomous UAVs make them relatively straightforward.

Photogrammetry usually involves HD and NIR cameras, and sonar radars. HD cameras capture light in visible range, and is suitable for constructing models as it is viewed by humans, such as 3D models or orthophotos. Supplements with radar measure relative altitudes to produce DTM and DSM. NIR cameras capture light just outside of visible range, which helps in situations with low visibility and poor light conditions, such as traffic or geological monitoring (Multipix, 2018). Fire intensity correlates with color and is also easily picked up by NIR (Cruz, 2016). All these sensors detect physical features, so they may be subject to privacy concerns, depending on how they are used. Figure 3 below shows grid-like positioning of UAVs to capture orthographic projection over a wide area. The individual photos are stitched together with software after.

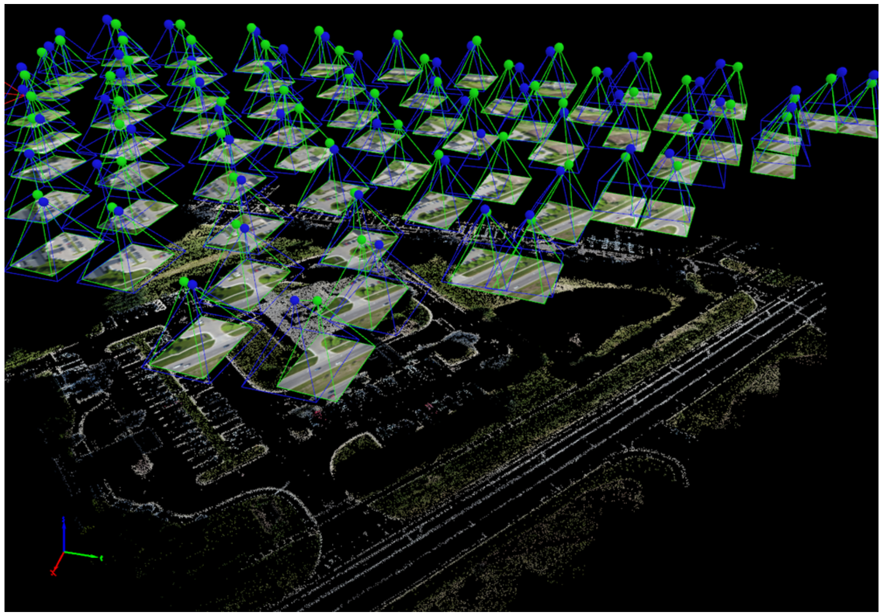

Figure 3: Simulation of photogrammetry for orthophoto creation (DroneView Technologies, 2016).

Despite that UAV uses in this category are mostly isolated from human monitoring, there remains some concerns that they are erroneously used such that they violate right to privacy. Particularly, fire and pollution coverage might take place over human settlements. While a number of scientists and fire departments have argued that UAVs save lives by helping fight fires and target pollution sources, and keeping fire fighters from flying over fires, civil rights watchdogs such as the ACLU says fire departments do not adequately address privacy concerns. The Stop LAPD Spying Coalition argues that allowing the fire department to record UAV visuals and radio communications provide a backdoor privacy violation if the recordings are ever shared with the police (Reyes, 2017). This is informally called mission creep, where uses are silently expanded from fire monitoring to surveillance (Evangelista, 2017). Although the LAFD has pledged not to commit surveillance using UAVs, it has not formally specified uses. Rights organizations say drone regulations must include oversight and accountability, and LAFD plans to adhere to informing public on UAV uses with quarterly reports (Reyes, 2017). Public dialogue and openness may be significant in public acceptance of UAV uses. For example, failure to address privacy concerns had prevented drone implementation in San Jose and Berkeley, CA. However, drones are used by other nearby cities with better public engagement (Evangelista, 2017).

Law enforcement and fire department argue that UAVs have great potential to save lives. The Center for the Study of the Drone in Bard College, NY, noted that 347 law enforcement units had acquired consumer UAVs in the 8 years before 2017. Many uses have been documented. For example, Fremont Fire Department used drones to fly 40 yards into the flooded Alameda Creek to look inside the window of a car that was drowning to check for survivors. The UAV tracked a survivor up shore and sent a GPS signal to pick him up. In Oakland, UAVs use thermal-imaging cameras to search for hot spots in a burning warehouse, where the fire could potentially reignite. UAVs in Fremont and Menlo Park were used to search for a woman and man whose kayak had capsized. Although the search failed, they saved time and resources by covering large areas. Fremont law enforcement used UAVs to find a missing Alzheimers patient. Highway patrol have used a UAV to determine if a man who had been involved with a shootout still had a gun (Evangelista, 2017).

While societal interaction remains on the forefront of ethical consideration, there are also concerns of wildlife disturbance. Studies have shown measurable stress-related physiological responses in animals that have collided with human artifacts, such as a decrease in productivity and avoidance of certain areas. Since UAVs operate in low altitude, they are susceptible to evoke disturbance (Mulero-Pazmany, 2017). However, studies have down that smaller rotor UAVs do not cause persistent effects on wildlife. A survey of arctic cliff-nesting birds have shown that 8.5% avoided UAVs, but 99% of them were not breeders. The survey noted no observable impact of UAVs on breeding success, as most birds returned to the nest within 5 minutes. Disturbed birds were rarely attacked by opportunistic predators. Over time, birds habituated to UAV presence. Birds in areas with eagles and other aerial predators were more likely to flush, although most birds do not approach UAVs close enough to collide (Brisson-Curadeau, 2017). Flight patterns, noise and size had an effect on animal disturbance. Direct and linear flight patterns of larger, noisier aircrafts evoked strong reactions, while some variance in the path of rotor UAVs minimized disturbance (Mulero-Pazmany, 2017). Wildlife monitoring at 20-25 meters were ideal. It should be noted, however, that bears have been shown to have physiological stress from repeated human exposure (Brisson-Curadeau, 2017). Animals that hide or aggregate as part of their defense strategy may not observably respond, and animals with offspring may prioritize protection. Therefore, regulation may be necessary to protect animals (Mulero-Pazmany, 2017).

Besides just counting specimen and identifying natural conditions, UAVs may be used to prevent illegal interactions between humans and nature. In the developing world, illegal poaching, logging, and mining remain large problems. The African elephant population declined 30% in the past decade due to poaching. At least 1338 rhinos – those that have been reported – were killed for their horns in 2015. These statistics are increasing as criminals become more organized and militarized.

Since 2015, UAVs have helped confiscate 18,000 illegal snares, making over 100 arrests. In the past, industrial UAV technology with machine learning and automation have been inaccessible to conservationists, either due to budget concerns or that they are typically technologically uninclined. Manual intervention were often required. Recent innovations bringing technology to the consumer and generous donations from the technology sphere, such as $5 million from Google donated to Malawis national parks, have reignited interest. UAVs can, for example, flash lights at trespassers, herd elephants by mimicking bees (Nuwer, 2017), and capture license plates of cars approaching conservation sites in case of illegal activity (Sandbrook, 2015). Machine learning advances developed by CMU, USC, and Microsoft can now automatically recognize humans with thermal imaging, and alert authorities through wifi, without requiring park rangers to tediously monitor low resolution security screens broadcasted by the UAVs at night (Johnson, 2018).

The versatility of these uses can be readily exploited, and unfortunately opportunists have begun to notice. Within monitoring applications, hunters in Canada have been using UAVs to find prey, and it has become problematic. It obsoletes guides and outfitters, and gives an unfair advantage, while making it hard for accountability of illegal hunting. Using UAVs for this purpose is illegal in Canada by the Wildlife Act, but difficulty of associating ownership means that no one has been charged (Burke, 2017). As testament to its severity, the Wildlife Act has recently been amended with a minimum $2,500 fine, with first-time offenders facing up to $250,000 and 2 years in jail (Meuse, 2016). In Africa, hunters have used UAVs to find rare animals and shoot darts to limit movement (Sandbrook, 2015). In America, gangs monitored police response of a hostage situation and broadcasted it to other members over YouTube. Joe Mazel, the head of FBIs operational technology unit, has said that counter-surveillance of law enforcement is a fast-growing criminal use of UAVs. Criminals have used UAVs to survey the vicinities of police departments to harass witnesses, and to spot security gaps and patrol patterns at major commercial facilities. At the border, cartels exploited coverage gaps of border patrol, limiting risk of entry (Tucker, 2018). Domestically, criminals have used UAVs to monitor homes, life patterns of the owner, and even the types of doors and locks used, to find potential burglary targets (Barrett, 2015).

5.2.3 Machine Learning on the Cloud

Since drones are practically limited in battery and processing power due to size and mobility, many applications call for off loading calculations to the cloud over wifi so that more complex operations could be completed. Although the cloud is ominously named, it is actually a network of always-on supercomputers. Since cloud operation is not specific to UAV use, this section will be brief. However, clarification on what constitutes machine learning is worth discussing to dispel fears over ethical concerns. Modern imagination of artificial intelligence (AI) is shaped by Hollywood movies like The Terminator or Odyssey 2001; however, the general intelligence that were depicted are not close to being actualized. AI today constitutes a series of graph-based and statistical algorithms, which includes machine learning. Learning, in this context, is dissimilar to any human conception of learning. Using conditional probability to find statistical likelihood is a simplification what the computer does. What needs to be noted is that, even under the latest AI system developed by Facebook or IBM, computers do not see vision or hear audio the way humans do. Computers are incapable of spatial recognition. A frame of a camera must be deconstructed into a linear array of pixels, or number values representing colors. Patterns in these numbers are what computers use to learn. Online image recognition sometimes use convolutional neural networks, a modern algorithm, that average number values into blocks to reduce computation complexity before computing convolution integrals. The resulting input is transformed by sigmoid or regularized linear functions to aid in finding parameters. Derivatives via gradient descent trains these parameters to find local optima. It is important to recognize, in the context of privacy, that there is no human-like consciousness residing in the operating system.

5.2.4 Ethical Background

Aside from technological concerns, several related issues should be discussed before we perform ethical analysis. Privacy is a sensitive concern, but perhaps widely due to misinformation. Recent survey showed that 58% of Australian and 75% of UK respondents deemed satellite monitoring an invasion of privacy (Sandbrook, 2015). At least some of this may be paranoia caused by science fiction ideas of satellites tracking private citizens, as depicted in the 1998 movie Enemy of the State. For example, most people seem to have accepted using Google Maps. Currently, the highest resolution satellite, WorldView-4, launched in 2016, is capable of 0.31 meter per pixel black and white images and 1.24 meter per pixel colored images (Satellite Imaging Corporation, 2017). This is about 1 feet and 4 feet, respectively. In other words, an adult lying down would be 5-6 grayscale dots in length, which is not enough to make out any discriminating details. Privacy is arguably subject to the type of sensing. HD cameras monitoring private property may violate privacy, but UAVs may be equipped with sensors that measure air particulates, ground water level, elevation, and other facts surrounding private property that is arguably either non-identifying to the property owner or regards public resources that pass through private property. Local ordinances, for example, have the legal right to dictate how water is to be used to an extent, especially in times of drought, even if water use occurs on private property. Sensor quality may also be relevant, since most UAVs available to consumers are limited in sensor ability and real estate (McNeal, 2014).

Several court rulings are relevant for UAV monitoring with respect to privacy. The 4th Amendment to the Constitution provides protection against unreasonable search and seizures of private persons and property. This indubitably includes monitoring by aircrafts. The FAA Modernization and Reform Act of 2012 regards UAVs as aircrafts, so this is a good angle to begin analysis. 1986 California v. Ciraolo ruled that people cannot reasonably expect privacy from common airplanes, so images taken from the navigable airspace of 1000 feet does not violate the 4th Amendment. For the same reason 1989 Florida v. Riley ruled in favor of the ability to use a helicopter at 400 feet altitude in surveillance of marijuana grown on private property. However, the earlier 1946 United States v. Causby ruled that, at 83 feet, the private occupiable airspace is a reasonable extension of private property. 1986 Dow Chemical Co. v. United States also ruled that aerial mapping with a standard aircraft does not violate the 4th Amendment. Therefore, there is a range between about 100-400 feet that remain legally uncharted (McNeal, 2014). For close to 30 years, however, there has been no expectation of privacy in monitoring by use of other technologies. The difference with rotor UAVs is that they typically do fly under 400 feet, so this ambiguity needs to be clarified. Figure 4 below shows the separation of public navigable airspace above 400 feet, and private occupiable airspace below.

Figure 4: Private occupiable airspace potentially starts below 400 feet.

Another ethical concern regards how it psychologically affects the ignorant populace, especially indigenous tribes. Irresponsible use of UAVs could cause hysteria and conspiracy theories if the public distrusts their use. Some Americans may point to UAVs as further evidence of deep state. Tanzanian folklore, however, suggests the existence of a batwing creature named Popo Bawa that swoops down and rapes victims at night, after paralyzing them with fear. The visual difference and low flight of rotor UAVs compared to conventional aircrafts might confuse people and cause undue stress. Hostility towards UAVs also increases costs, since people may be tempted to shoot them down. A US ad campaign drew attention when it depicted a shotgun silencer as heroic Defender of Privacy that shoots down UAVs (Sandbrook, 2015).

5.2.5 Ethical Analysis

We perform ethical analysis using Kantian deontology and utilitarianism. Through deontology, we show that UAV usage would not cause any inherent bad that renders society unserviceable. Through utilitarianism, we show that UAV usage is net positive on increasing civilian quality of life. Since deontology is favorable to the minority, and utilitarianism is favorable to the majority, together we hope to show that UAVs are beneficial overall.

A number of maxim could be proposed to support both the universality and reciprocity principles, but care must be dedicated to the nuance so that they satisfactorily address all concerns. A maxim prescribing unfettered drone use to reduce cost, when universalized, must also be subject to uses that reduce cost of criminal enterprises. All selfish uses cannot coexist, thus leading to contradiction. In contrast, a maxim prescribing illegalization on account of potential harm should, when noting analogous similarities to other technologies, advocate illegalization of everything for which there are potential harms. A number of existing technologies, such as cars or other aircraft, have capacity to cause similar harm, yet they numerous benefits that we take for granted. A contradiction arises when we accept one but not the other, given the same factors in the decision. A solution must show balance.

Suppose the maxim that UAVs are desirable on public property, in order to address privacy concerns. However, there are criminal uses on public property as previously discussed, and private monitoring on public property is sometimes possible. If this maxim is accepted, the reciprocity principle would be violated since there would be no privacy in public, and it would be possible to use people as means. We need to significantly reduce acceptable application.

To clarify, we prescribe the maxim that UAVs could only be publicly used or used on third party property to mitigate direct risks to loss of life, and to measure some natural quantity. We note that this limits most private uses of UAVs toward surveillance, especially surveillance of human populations. An arguable exception may be to take census, if humans are considered part of nature when no individually or socially identifying characteristics are discernible, but this is a stretch. Notable exceptions for private could be to monitor a burning building, conflict resolution, farming, or uses by the owner of a private property. This supports the universality principle trivially, by elimination of conflicting uses. Life should always be protected whenever possible, and monitoring in nature is already possible, although UAVs improve its effectiveness. Therefore, by universalizing, nothing significant changes. It also supports reciprocity, if we assume that life is valuable to all, and that public monitoring harms no one. These uses do not use people as means. The problem lies in enforcement of such, to ensure no violations ensue.

One way to address potential violations is to prescribe that data from public monitoring should be made publicly available. This satisfies universality since public property is already publicly accessible. However, public data that inadvertently contains private information should be deleted. A third party arbiter of these conflicts should ameliorate this concern. Therefore, we prescribe a second maxim that a system should be in place for citizens to redress UAV uses that violate prescribed standards. Universalizing, we prescribe a system of openness and accountability, and both ideals satisfy the Kantian principles.

Since ethics does not exist in a vacuum, the consequences of these prescriptions are that UAV usage heavily relies on the pretext of sufficient infrastructure in both regulation and arbitration bodies. In order to seriously move forward ethically, the public should be courted with this sufficient level of trust. Only then can we believe that UAVs are used to proper ends, and that improper uses can be addressed.

We have shown that proper infrastructure allows righteous UAV use to be possible, but righteous use is not necessarily beneficial use. We now establish that UAVs are indeed beneficial. The primary interest in question is the public. Possible actions include, for sake of completeness, unfettered legalization, illegalization, and limited use as previously described. We note that the proper uses of UAVs, as discussed in previous sections, save millions of dollars with increased functionality and capacity to save lives. Specifically, while the 2 UAVs used by the LAFD cost \$6,600 (Branson-Potts, 2018), fire monitoring with helicopters cost \$32,000 a day to maintain, and the fuel and pilots to fly for an hour costs \$6,300 (Cart, 2008). Assuming UAV lifetime is 5 years, they will presumably be in operation for hundreds of hours. In pollution monitoring, the UAV used by UCLA costs \$400, plus some thousands for the portable particulate monitor, but a beta attenuation monitor costs \$100,000 plus weekly maintenance. Since the latter is fixed and too heavy to move around, its coverage is much less than the UAV, so there would need to be more for equivalent operation (Choi, 2017). In the case of bridge repair, a snooper used to reach under the bridge for inspection costs more than \$1,000,000 (Bliss, 2007). Since the truck-sized machine needs to be parked, it takes up a lane on the road. Depending on the time of day – and inspection must occur during expensive day time hours – lane closures might cost up to \$10,000 every 15 minutes (FHA, 2017). The Albris senseFly purchased by Minnesota to do bridge inspections, however, only cost \$10,000 to \$25,000 plus electricity, and it does not require lane closures. These are just several uses out of many, but economic savings are huge. This does not account for hidden cost savings that may arise from results of the monitoring activities. For example, accurate pollution monitoring may help enact legislation to address sources quicker, and accurate animal counts may help save them from extinction. In many applications, UAVs have irreplaceable functionality that may save lives. The utility from the latter is hard to quantify, but it must be significant. Table 2 below summarizes the cost differential for 4 applications when comparing UAVs to the status quo. Economic cost of UAVs significantly beats the alternatives by a large margin.

Table 2: Costs of UAVs against the status quo alternative is greatly optimistic.

Applications	**Options**	**Description**	**Cost**
Fire	UAV	2 DJI Matrice 100 with cameras	\$6,600
	Alternative	Helicopter, pilots, fuel, insurance	\$65,000/day (Cart, 2008)
Pollution	UAV	DJI Flame Wheel + c-Air monitor	\$2,400 (Choi, 2017)
	Alternative	Beta attenuation monitor	\$100,000+maintenance
Bridges	UAV	sensefly Albris with cameras	\$10,000
	Alternative	Snooper, lane closures	\$1,000,000 (Bliss, 2017) +\$10,000/15 minutes (FHA, 2017)
Construction	UAV	Drones with cameras	\$6,000
	Alternative	Team of professional surveyors	\$100,000

The cost of UAVs include imaginary and real. Imaginary costs have real effects. Paranoia about UAVs, even when unfounded, cause psychological stress and political friction. The fight over their legalization must amount to something in the millions, but it is hard to find an exact figure. The fact that Amazon spent \$9.4 million lobbying for UAVs in 2015, double of what they spent in 2014, gives an indication (Yakowicz, 2016). Real costs includes actual privacy violations, defense against security and terrorism concerns, and counters against burglars, gangs, cartels, and other criminal enterprises that use UAVs. It is important to note that UAV parts and technology are ubiquitous and easily sourced from 3D printers and hobby stores for electrical engineering and robotics, somewhat unlike guns, which require precision metalwork and dangerous gunpowder. A second difference is association of ownership. A criminal that uses a gun is easily culpable, but since UAVs can be controlled remotely or autonomously, it becomes difficult to track criminals behind crimes committed. In fact, the US Department of Homeland Security have said there is no safe mitigation technologies available at this time for UAVs (Winter, 2018). Criminals could attach weapons or explosives to UAVs and fly them to major events. If electromagnetic pulse (EMP) is used to disable flight, they would fall down and endanger people underneath. Although no UAVs have been intercepted so far (Winter, 2018), these factors should be convincing that high demand and rampant supply means that criminal UAV uses must be considered regardless of legalization.

We should hope to maximize proper UAV uses through legalization, but minimize improper uses through regulation. As research into UAVs advance, and they must in order to deal with improper uses, the exact means in which these uses occur will be clarified. But since research is necessary, UAVs might as well be legal. If they are not legal, such that research is more difficult, criminals will be given an advantage. Technology advancements will be imported from other countries even if they are illegal here, and there is relative ease for UAVs to cross borders. Therefore, if unfettered legalization leads to proper use and great improper use due to both criminal enterprises and opportunistic capitalism, and making it illegal leads to no proper use and moderate improper use, we hope that legalization with regulations would lead to proper use and minimal improper use, thereby maximizing positive utility and providing the greatest benefit for the greatest number of people. Table 3 below summarizes the corresponding utilities for each action.

Table 3: Legalizing UAVs with regulations as discussed maximized utility.

Actions	**Positive Utility**	**Negative Utility**
Unfettered legalization	Great	Great
Illegal	None	Moderate
Legal and regulate	Good	Minimal

5.3 Proposed Solutions

We propose comprehensive changes to existing law to address privacy, security, and minimize unintended consequences, while allowing for all the proper monitoring uses of UAVs. Existing law contains some ambiguities that leave details up to future legal administrations, which could pose disastrous consequences, if our current situation is any bearing. Lawmakers are sometimes overly ambitious or fearful and try to write regulations for the future. Instead, responsible regulation would address technology today, but leave room for future alterations. Fear without a complete understanding leads to odd consequences.

So far, 11 states require warrants for UAV use specifically, which is a focus on technology but not privacy. This disregards the fact that there are other existing technologies with the same functionality for some uses, but it also prevents legitimate uses like documenting crime scenes (McNeal, 2014). The warrant-based approach is too limiting. It stifles innovation, increases barrier of entry for scientific or academic uses, and prevents public event uses such as monitoring the Boston Marathon (McNeal, 2014). Such limitations might have put runners at increased risk, where participants of such events could be asked to waiver privacy concerns to improve safety. We suggest an alternative approach to accountability with a hybrid technical solution. First, all legal UAVs in the country intended to be used publicly should be produced with the function to report some identification information upon being polled. A national standard of requiring the ability to accept a certain frequency of poll requests at a standardized public-facing port via Bluetooth should be imposed. An external device could poll any UAV for identification, and a digital signature would be returned that can be verified by trusted authenticators. All UAVs would be registered to a public database containing owner information, intended UAV uses, intended areas of use, contacts, and equipped sensors. Registration confers legal accountability, and polling a UAV with an official polling device saves a GPS coordinate, which could be used as legal evidence in case of trespassing. Property owners may purchase these polling devices to hold illegal surveillance accountable.

Legislation should clearly specify allowed altitudes and fly zones for UAVs. We propose that rotor drones remain under 100 meters, or 300 feet, in altitude to navigate privately occupiable airspace, subject to more stringent privacy laws. However, altitudes above 300 feet become publicly navigable airspace and subject to more stringent FAA regulations to prevent aircraft collision. UAVs that navigate in high altitudes must be fully considered an aircraft, while lower altitude UAVs deserve special status. This allows lower barriers to uses such as pollution monitoring. As McNeal also suggests, machine learning and GPS could be used in conjunction to auto-redact private information within a geo-fence (McNeal, 2014).

To protect privacy, government uses of UAVs should regularly delete public data, and make all long-term stores of public data publicly available. Private citizens could freely access this database. Any information could be contested if perceived to contain privately identifiable data. These cases would be handled by an independent arbitration party. Law enforcement units and fire departments should specify exactly which circumstances allow UAV use, to prevent mission creep. They should also specify whether data can be shared between agencies.

A possible technical solution against rogue or criminal UAVs is to have government patrol UAVs fly around cities, and poll other UAVs at every instance. UAVs that fail to respond within 3-5 retries are quarantined by surrounding it with a net. If the drone is found to be legally registered and had either encountered minor malfunction or if the non-response is due to some benign reason, then the owner could be let off with a small fine or no fine. However, if the drone is criminal or intentionally tampered or hacked, then it is escorted to some isolated area.

With these combinations of technical and non-technical solutions, we believe we can reduce barriers for proper drone uses while impeding adoption and successful improper uses.

Chapter 6

Service

6.1 Background and Applications

Surveillance is not the only use of UAVs. Due to their small form factor and ease of maneuverability, UAVs have great potential in journalism and delivery. The pros and cons of drones for parcel delivery, journalism, and healthcare will be discussed in detail. In the case of delivery, UAVs can be used to deliver parcels as well as healthcare supplies at a rate much faster than conventional methods. In the case of journalism, UAVs have the potential to reduce casualties and increase flexibility.

6.1.1 Parcel Delivery

Mail has been an integral part of communication since people first started coming together in societies. The capability to send and receive physical goods for a very affordable price is almost taken for granted. As technology has advanced over the year, mail systems have become more efficient. Mailing has become more secure, trackable, and expedient as transportation and computer logic technologies have improved. It stands that the mail system can become even more refined in the future, and a survey of our current body of knowledge would point to drones leading the way for a mailing revolution. Prospective mail delivery services such as Amazon Air advertise deliveries in under 30 minutes, and USPS claims savings of $50 million in savings for using drones by having them replace the 66 thousand workers for a single trip cycle. Drones can be applied to the current system of mail delivery by effectively replacing the use of human mail carriers. The benefits of this are manyfold. First and foremost of these benefits is that drone delivery is both faster and more reliable when compared to a human carrier. That is to say, drones do not experience fatigue and travel at a predictable rate at all times. This would enable mail recipients to have accurate and reliable estimates of when packages would arrive.

Logistically, drone carriers are superior to human carriers because of their ability to navigate terrain at a cheap price. This manifests itself in the delivery business as the so called last mile, which is the term for the distance between the delivery van to the recipient's doorstep. Human carriers have to physically step out and navigate this distance. Many factors, namely the inaccessibility of the destination location, ambiguity regarding where to place mail, and sheer time of travel, make this the most cost ineffective part of mail delivery. Drones would be able to rectify this problem nicely because of their method of travel. It costs the same for a drone to travel in the air from the mailing center all the way to the drop off location of mail because of pre programmed flight instructions and the logistics of having a flying machine versus a walking human. In a sense, the most difficult part of the journey is made simple because of technology.

The concern with new technologies is always their unreliability compared to the status quo. The use of drones is no different when it comes to introducing them to the mail delivery process. Critics question primarily the security of drones when it comes to mail. A certain degree of privacy and reliability is expected when receiving mail. It would be unacceptable if a vandal were to intercept drone mail carriers and make off with mail. This concern is not invalid, but is ill found because of the many measures that innovators are taking with drones. Locked carrying compartments, as strong as conventional home safes, and alarm systems make drones into walking security robots, more robust than any human carrier could be.

6.1.2 Journalism

Credible journalism is a valuable part of any modern society, as it maintains an informed populace. In the realm of credible journalism, eyewitness news, in which reporters generally report live from the place or event of interest, serves to assure watchers that information is accurate. However, this dedication to authenticity comes with a caveat. Eyewitness reporting can put the reporter at considerable risk; in 2012 alone, 152 reporters died, mostly due to reporting in dangerous areas such as warzones (Gynnild, 2014). Additionally, there are situations in which human coverage is unfeasible. A large natural disaster could, for example, wipe out infrastructure and make it impossible or extremely risky to reach a location by foot.

In recent years, drone journalism, in which UAV are used to for journalistic purposes by both professionals and amateurs, has gained prominence. Though the technique was used intermittently throughout the past couple decades, it was not until the Occupy Wall Street movement that drone journalism really took off. The success of amateur journalists in using UAVs to livestream the event and bring awareness to the situation led to major news outlets to catch on and adopt the technology.

The UAV is an ideal alternative to a flesh and blood reporter due to its decreased risk of loss of reporting personnels lives. The UAV is just an easily replaceable machine, but a person is certainly not. In a warzone, for instance, drone journalism allows journalists to remain a safe distance away from danger. The worst case scenario would be the loss of an easily replaceable UAV rather than that of a human life. As the majority of reporter casualties come from warzones, this would greatly improve work safety.

Additionally, UAVs allow coverage in areas that flesh and blood reporters were not able to cover before. UAVs also offer a variety of different perspectives, such as birds eye view, that the average human reporter can not. In other words, drone journalism is preferable due to the lessened risk and increased ease of entry and flexibility of perspective. For example, UAVs made it possible for major news outlets to capture video and images of Typhoon Haiyan in the Philippines. Such coverage would not have been possible if reporters had been on foot due to the collapse of local infrastructure and lack of power caused by the typhoon (Holton, 2015). Such a drone image can be seen in Figure X below, a picture taken by a drone following Hurricane Maria. But with UAVs, news outlets were able to quickly gather vital media and share with the world the devastation that the Typhoon had caused, all without subjecting their reporters to life-threatening conditions. News outlets are increasingly relying on footage from private citizens. In 2014, footage captured with permission by Brian Wilson, a citizen, was used widely among news organizations. With his UAV, Wilson was able to capture footage of the incident before all major outlets and at angles that news helicopters are unable to reach (Holton, 2014).

Figure 5: Picture of damage done by Hurricane Maria, taken by a drone (Arduengo, 2017).

On the downside, drone journalism is subject to much of the same technical and ethical concerns as any other drone-related application. Concerns have been raised, for instance that the use of UAVs in crowded public areas or active disaster scenes could potentially be dangerous. Factors such as radio interference and strong winds do have the capability to bring down a drone with potentially devastating consequences if the drone is in a crowded area. However, this concern is for the most part invalid, as current methods of gaining aerial imagery involve much larger and potentially more devastating transportation vehicles. For decades, the method for obtaining aerial imagery and video has been the helicopter. However, the helicopter has a much greater capacity for destruction than the common UAV. In 2014, helicopters were found to be on the more dangerous side of transportation vehicles with a crash rate of 9.84 per 100,000 hours, much higher than that of all aircraft and driving (Holton, 2014). The UAV is thus a better option due to its smaller form factor; UAV crashes are much less likely to be fatal than those of helicopters. Additionally, UAVs are also drastically more cost-efficient than helicopters. Helicopters cost hundreds of thousands of dollars and have high continuing operation costs. In previous decades, news corporations have had to spend great amounts of money into hiring helicopters, planes, and professional aerial photographers when the needs arise (Gynnild, 2014). A UAV good enough for journalism can in contrast be permanently bought for less than a thousand, require much less training and personnel to use, and features perspectives and speed that a helicopter can not. In fact, it is expected that the cost of operating UAVs is likely to drop to below $10 an hour as the technology improves (Holton, 2014). UAVs even have the potential to replace conventional ground journalism, which requires bulky and expensive equipment and skillful maneuvering to engineer the desired perspectives.

Thus, those with concerns towards drones should realise that UAVs are in fact much better than conventional methods. They are safer, cheaper, and more accessible. The issue with privacy that many have raised is also somewhat trivial, as the drone is just a new format of aerial journalism. News outlets have been recording and broadcasting video for a long time, and the use of a drone instead of a helicopter or set of reporters does not change that fact. Thus, due to its cost efficiency, lesser risk in usage, and greater adaptability the drone proves itself as a viable alternative to current technologies for eyewitness accounts.

The biggest barrier to drone journalism is government regulation. Regulations by the Federal Aviation Administration, or FAA, have stopped drone journalism from advancing much in the past decade. As recently as 2014, it was virtually impossible to get permission to use UAV for journalism. The FAA defines journalism as commercial use, and at the time prospective pilots had to obtain an airworthiness certificate before they were legally allowed to operate an UAV. However, in addition to being extremely difficult to obtain, airworthiness certificates also required users to document in advance when and where they plan to use their aircraft. As drones are mostly used for breaking news and disasters, these regulations ensure that in most cases it is impossible to use a drone for news (Holton, 2014).

The FAA has been loosening regulations, but drone journalism is still only possible in select situations. Under the small UAS rule, it is possible for someone to fly for both recreational and commercial use as long as they register their drone and get a Remote Pilot Certificate. However, flight is still heavily restricted; drones must be within visual line of sight and under or at 400 feet, and only during daylight or civil twilight. Flight near other aircrafts of over people is not allowed (FAA, 2018). This aspect of UAV operation may change in the near future. In 2017, CNN became the first to receive permission to fly over people, a critical step forward in the normalization of UAV for newsgathering (CNN. 2017). Once it is no longer hindered by regulations, drone journalism is likely to become the next standard in journalism.

6.1.3 Healthcare

In emergency situations, such as a severe car accident, peoples lives depend on the time it takes first responders to reach the incident location. Unfortunately, current technologies, such as ambulance vehicles, are inhibited by variables such as traffic, often arriving too late to the scene. This problem is exacerbated in rural areas, which are normally far from help and have considerably less access to useful resources. In the United States, for example, only about 11% of physicians work in rural communities (Bhatt, 2018). A shortage of physicians, proper equipment, and proper infrastructure are thus substantial problems in healthcare.

These issues can potentially be solved by UAVs, which are unaffected by traffic and lack of roads; they can transfer crucial medicals supplies much faster than conventional methods can. UAV healthcare delivery has already proven its worth, greatly aided countries devastated by natural disasters or plagued by the lack of a good road system. For example, the drones of Ziplines distribution centers in Rwanda have made more than 1,400 flights and covered over 62,000 miles. The company will be expanding in 2018, launching another base in Rwanda as well as starting service in Tanzania. Thus, drone healthcare delivery is clearly viable (Landhuis, 2018).

A major advantage of UAVs in healthcare is speed. In Germany, company DHL Parcel has researched and developed drones for delivery of blood and medications. Through testing, they found that drone delivery was significantly faster; between two Bavarian Alpine villages, the round trip in winter took 30 minutes via vehicle but only 8 minutes via drone (Scott, 2017). In an emergency medical situation, this time difference could very well also serve as a difference between life and death. While right now UAVs are mostly used to deliver supplies such as blood and lab samples, they have the potential to do much more. For instance, a drone could be equipped with an AED. As the survival rate of someone who is suffering from cardiac arrest decreases by as much as 5% per minute, AED-equipped drones could prove vital in increasing the survival rate for out-of-hospital cardiac arrests (OHCAs) by reaching the victim far faster than conventional methods.

Additionally, in some cases drone delivery is potentially cheaper than the conventional method. Simulations have found that in Gaza, a drone vaccine delivery system could increase vaccine availability by 2% as well as reduce cost by $0.08 per dose administered (Bhatt, 2018). With a potential combination of better response time and cost, drone healthcare delivery has the potential to save many lives.

Delivery is not the only aspect of healthcare in which the drone shines. A recent study in Sweden studies the effectiveness of using drones to identify drowning victims at beaches. Results found that drones could identify victims around 3 minutes and 38 seconds faster than lifeguards. Similar studies were conducted in the mountains that found a significant decrease in the amount of time taken to find stranded victims from 60 minutes to 10 (Bhatt, 2018). Though studies have not yet been done on this application, health surveillance via drone on recently released patients or those at risk could also be an effective usage of drones, allowing doctors to monitor those and risk and respond promptly in the case that something goes wrong. However, healthcare monitoring via drone is subject to the same concern towards privacy that plagues most drone applications, so whether it is possible or effective remains to be seen. The biggest limit on drone healthcare delivery, however, is the need for drone nests to provide sufficient coverage. Installation of such a system would require great amounts of coordination between local authorities. Additionally, great care must be taken in urban areas to insure that drone delivery paths do not interfere with existing air traffic, such as airports. There are many technological concerns towards the viability of drones, as their susceptibility to poor weather conditions and hacking may cause them to lose their functionality as well as be a danger to their surroundings if they are carrying supplies such as microbiology. All in all, however, the widespread usage of drones in healthcare remains very promising.

6.2 Ethical and Societal Considerations

The background of ethical concerns towards drone usage has already been described extensively in section 5.2. Thus, in this section only the ethical and societal considerations of the specific service-related applications of drones will be discussed to avoid unnecessary redundancies. Utilitarianism and Kantian ethics will be used to analyze the morality of these applications.

6.2.1 Parcel Delivery

While drone delivery saves companies a lot of money and consumers time, it also results in many delivery workers losing their jobs. Thus, evaluation of the ethics of drones versus humans via utilitarianism is appropriate in this case. In parcel delivery, the main parties involved are the delivery companies, consumers, and delivery workers who will be replaced by the UAVs. Replacing delivery workers with UAVs saves the companies enormous amounts of money. UAVs are also more convenient for consumers, as they deliver faster. However, the replaced workers are now jobless. In terms of satisfaction, the most people are satisfied if the delivery workers are replaced by UAVs, given the ratio of consumers to delivery workers is greatly skewed towards consumers. Additionally, the amount of money that the companies save is quite substantial. In contrast, delivery workers are only a small subset of the population. The delivery workers also have the ability to find other jobs if they put in the effort. Thus, the utilitarian choice would be to replace the workers with drones to reap the maximum benefit for all parties.

Another concern with drone delivery is consumer perception. As shown in the figure below, the majority of consumers are hesitant that drone delivery is viable; only around 30% believe that drone delivery is safe. Even if theoretically drone delivery is better than current methods, it does not matter if the majority of consumers do not really care for it. If society is not yet ready for drone delivery, then implementing it now is not the best idea.

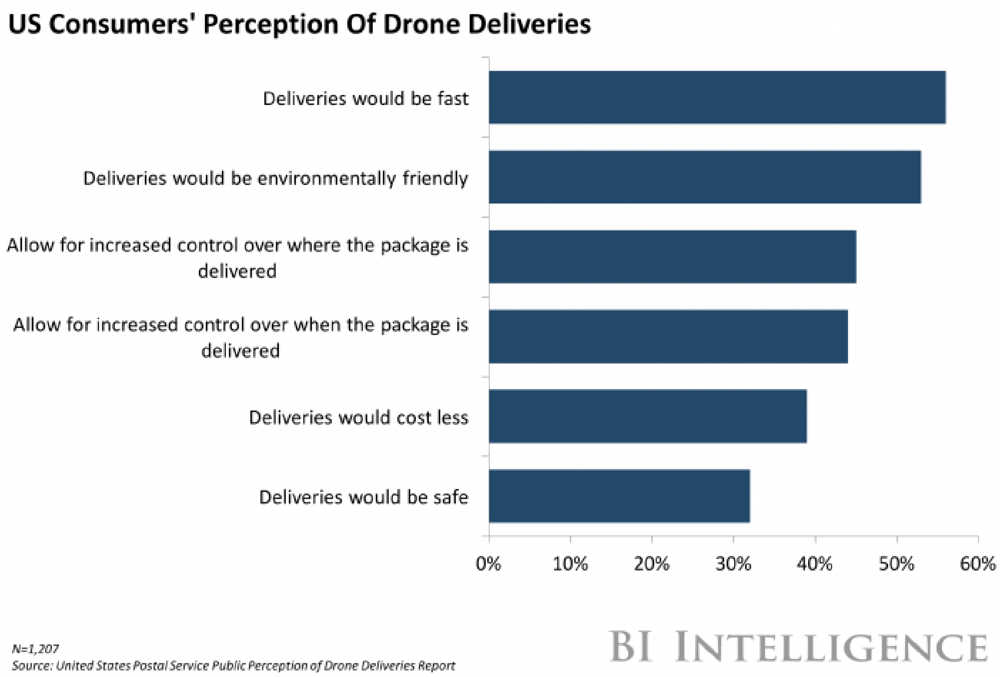

Figure 6: Bar graph of consumer perception of various aspects of drone delivery (Business Insider Intelligence, 2017).

6.2.2 Journalism

The ethics of using UAVs in journalism can be discussed using utilitarianism. The affected parties are the journalists and the news companies, and the actions that can be taken are to continue risking lives on the frontline or to switch to UAVs. Switching to UAVs is beneficial for both parties in this case. The journalists greatly reduce their risk of death, as they no longer have to physically go to dangerous places. The company likely saves a lot of money, as drones are cheaper than helicopters and also much easier to replace. Drones are also much safer than helicopters. It is clear that drone journalism is the most optimal choice; it maximizes benefit for both reporters and the companies the reporters work for.

6.2.3 Healthcare

The ethics of drones for healthcare delivery is very similar to that of parcel delivery. We can again perform an utilitarian analysis to determine whether healthcare delivery is the moral option. In healthcare delivery, the involved parties are the companies using the technology and potential. The companies potentially save money or break even. The potential patients benefit greatly from the better response time; one can expect that the fatality rate in accidents will drop due to the faster delivery of crucial supplies. Thus, healthcare delivery is the moral choice.

6.3 Proposed Solutions

As noted, UAVs can be used impactfully in parcel delivery, journalism, and healthcare. However, it is important to ensure that its use has ethical boundaries. A limitation that all three types of drone service must apply is keeping their use moderated. Duty ethics and utilitarianism provide stable ethical frameworks that these moral regulations can be drawn from.

The use of UAVs for parcel delivery should be moderated lest their use be harmful to the public. Undoubtedly, using UAVs for this purpose will result in a decrease in jobs that are available for citizens. However, for this reason it is necessary to ensure that the use of drones for this application is not excessive. It is important to moderate the use of drones for delivering mail so that some jobs will still be available to the public. A maxim to consider states there should be enough jobs available for people who want to work to be able to work. While this is unlikely to hold in todays society, it is desirable for it to be universal law because then no one would have to worry about being unemployed. With a maxim that promotes job availability, people are the end rather than the means, which passes the reciprocity principle. Moderating drone use for parcel delivery therefore has a positive impact on people on a personal level, but it also benefits the society as a whole. One result of there being more jobs and thus more workers is a more thriving economy. With more people working, there are more people to purchase items in stores, which allows businesses to thrive and results in the government benefiting from taxing these companies. Thus, this moderate usage will simultaneously promote the collective interest of society and the individual interest of the working class.

When using UAVs for journalism purposes, it is important to do so in moderation to preserve jobs as previously noted. In addition this restriction, it is also important to make sure that these drones are not used to invade peoples privacy. News outlets often desire to have greater audiences that watch their news reports, which would result in higher ratings. However, if drones were used for news stories, reporters may be tempted to use them to uncover more information about the story by invading someones privacy. Whenever someones privacy is infringed, it is a breach in the victims natural right to liberty (US 1776). A maxim to consider is, the common citizens privacy should be respected and reinforced. The common citizen is not the means, but the end, in this maxim so it abides by the reciprocity principle. On the other hand, it can be made universal law because it would protect citizens from having their natural right to liberty violated and promotes their moral autonomy (US 1776).

There is significant potential to using drones for healthcare purposes, but there are still elements that need to be considered for this application. Using UAVs for healthcare comes with the risk of the devices interfering with existing air traffic. Duty ethics framework states that a given right has an associated duty that is tied to it. The right to use UAVs for healthcare comes with the duty of ensuring that these devices do not interfere with the established air traffic. Having this kind of interference would threaten the common citizens safety. A study that was done by the Federal Aviation Administration involved simulations that determined that an aircraft collision with an unmanned drone is much more damaging to the aircraft than a bird with the same initial kinetic energy (FAA 215). This is because of the dense and rigid construction that unmanned aircraft systems (UAS) have as well as their high-density UAS components (FAA 215). Airplanes are designed to be able to withstand collisions with birds, but not with drones. Since this the case, making drone use more common in civil zones would compromise the safety of everyone who is in the airplanes that fly near these drone areas. In addition, if a drone were to be struck down or run out of battery mid-flight it would descend with a meteoric speed. This would be a significant hazard to people who are in proximity of these drones. To abide by the utilitarian value of maximizing the happiness of the public, it is very necessary to regulate drone usage for healthcare to ensure that it does not interfere with air traffic.

Chapter 7

Warfare

7.1 Background and Applications

Thus far in this paper, drones have been discussed in the civilian and research sphere. However, drones are also widely used in and originated from the military context; they are an important component of any discussion about the USs current campaign in the Middle East due to their widespread usage. Drones are capable of feats that human soldiers are not; they can recognize people and places of interest from up to two miles in the air, perform targeted strikes, and transport supplies. The usage of drones in warfare has the potential to save the lives of many soldiers by taking people of off the front lines. However, there is also much controversy surrounding their usage due to the high level of civilian casualties. Drone warfare will be discussed in the context of the U.S. military efforts.

7.1.1 Scouting

The documented development of drones for military application began as early as 1916 with the U.S. interest in flying bombs, but no aircrafts built during the time were operational, and most were unable to fly for even short periods of time. The first widely successful unmanned aircraft was developed by Germany in WWII. The V-1, nicknamed Buzzbomb, was capable of speeds up to 400 mph. In the UK, the Buzzbombs caused more than 6,200 casualties and more than 18,000 injuries (Cook, 2007).

After World War II, drones were mainly used as a form of surveillance. Motivated by the preventable downing of Powers U-2 in Russia and a similar incident during the Cuban Missile

Crisis, the U.S. awakened to the potential of drones. UAVs were used in the Vietnam War to perform reconnaissance at a fraction of the cost and risk of traditional methods (Cook, 2007).

In warfare, information is the key to victory. Current drone-based surveillance technologies can provide crucial intel without any risk for human casualty, providing valuable intel on the locations of enemy places and peoples of interest. With this intel, commanders can formulate plans that maximize reward and minimize casualties. In recent years, drones have become a mainstay in military scouting, and technology in this application is rapidly improving. Before the advent of the UAV, surveillance was traditionally done by ground troops or manned aircrafts. However, both of these methods have a greater risk for loss of life as they leave soldiers susceptible to attacks. In addition to bringing the risk of casualty down to roughly zero, UAVs are cheaper and faster to deploy. It can take 6 weeks to teach a combat pilot how to fly, which is 17 times longer than the time it takes to build a Pioneer model UAV with similar surveillance capabilities. UAVs are also smaller and lighter than manned aircrafts, making them less likely to be seen and faster (Hajiyev, 2015). These savings in expenditure and human life make it hard to argue against the use of drones for military surveillance.

One common UAV today is Northrop Grummans Global Hawk, which has an endurance rating of over 32 hours and state-of-the-art sensors. The Global Hawk is able to fly at altitudes of up to 60,000 ft and has an operational range of 12,300 nautical miles while taking and relaying back high quality image and sensor data (Northrop Grumman, 2016). Powerful UAVs like the Global Hawk can greatly accelerate wartime efforts. For example, one Global Hawk alone is credited with locating at least 13 surface-to-air missile batteries, 50 SAM launchers, 300 canisters and 70 missile transporters; this is no small feat. In the Iraq campaign, the Global Hawk was lauded for shortening the span of the war and reducing casualties far beyond initial expectations (Cook, 2017).

Besides providing vital intel, constant drone surveillance has proven to be a successful deterrent and source of paranoia for insurgents. The paranoia was so strong in Pakistan that some Pakistani no longer drank Lipton tea out of fear that the CIA put homing beacons for missiles in the tea bags (Callam, 2010). In other words, the constant surveillance prevented insurgency and also dissuaded potential insurgents by causing them to fear retaliation.

7.1.2 Combat

It was the weaponized Pioneer developed by the Israeli Air Force that really kicked off U.S. military use of drones (Callam, 2010). So frightening and recognizable was the sound of the Pioneer that during the Gulf War, Iraqi troops of Faylaka island surrendered to the UAV, realizing that the presence of the drone overhead meant certain defeat.

UAVs in the hunter-killer context, such as the Pioneer, provide many benefits over traditional methods. Traditionally, strikes must go through multiple levels of confirmation and authorization before they can be completed. This process can take up to three days, at which point the target could be long gone, or the location could be compromised by civilians. With UAVs, however, strikes can be confirmed in a matter of minutes. The moment the imaging technology on the UAV detects the target the weaponry on the UAV can be used to eliminate it. Additionally, there is generally no risk of pilot death with UAVs, as it is possible for a pilot to control an UAV from the other side of the country. Thus, more risks can be taken. The drone can get lower and loiter longer than a plane can, allowing for more accurate strikes and less risk of civilian casualty.

However, as shown by the wars against insurgency in the Middle East, civilian casualty is still common even with drones. On August 5, 2009, missiles launched from the Predator UAV successfully eliminated Baitullah Mehsud, the leader of the Pakistani Taliban (Callam, 2010). In the U.S. and in government media, the kill was regarded with high praise and exaltation. But the reality was far more grim. The fatal strike in in August was not the first attempt at Mehsuds life; it had taken sixteen strikes, fourteen months and between 207 and 321 additional deaths to finally kill him. Mehsud was successfully eliminated, but at the cost of the lives of innocent civilians. False identifications are also not an uncommon occurrence; an innocent villager was mistakenly identified by a drone as Osama bin Laden and eliminated along with his two equally innocent companions (Callam, 2010). High rates of civilian casualty also have a chance of creating more militants than are being eliminated, driving frustrated civilians towards supporting and even perhaps joining the enemy.

Another problem with drones is the disorientation that it causes pilots. Pilots of UAVs can be on the other side of the globe yet still see in vivid detail the damage that they cause. In the words on one pilot, flying a drone is a dramatically different experience from flying a manned aircraft, say that it is quite different, going from potentially shooting a missile, then going to your kids soccer game. A former F-16 pilot says that dropping bombs when piloting a manned aircraft is much more dehumanized, as you drop a 500-pound bomb and then fly away (Wall, 2011). While dropping a bomb is of course no small feat, the pilot of a bomber usually does not get to see the aftermath of their action but simply following a routine. In contrast, with the drone the pilot is forced to see the consequences of their actions, as they get to see the damage and devastation that a missile strike causes. Thus, even though UAV pilots are distanced from the action, they may actually feel the consequences of their actions and dehumanize their targets less than the bomber pilots who are on the scene.

7.2 Ethical and Societal Considerations

It is important to have a viable ethical framework to base the use of UAVs in warfare on lest their use be soiled by corruption. Utilitarianism can be applied to find out whether all parties experience maximum happiness when drones are used for war. Deontological ethics can be used to set boundaries on the use of UAVs for warfare by limiting civilian casualties and preserving the lives of allied troops.

War in general, particularly the war on insurgency, in which the U.S. is largely viewed as an outsider, is highly controversial. The high rates of civilian casualty and the constant fear that it has put locals on has made the cost-benefit of drones something highly contested. With Kantian ethics, it is clear that both drone surveillance and hunt-kill operations are wrong. In both cases, it is inevitable that civilians will be treated as mere means to an end, violating the reciprocity principle. This is a problem with war in general, making Kantian ethics perhaps not the best primary framework to gauge the ethics of drone warfare. Thus, utilitarianism is used to provide a cost-benefit analysis and determine whether drone warfare provides the maximum pleasure to all parties in Table 4.

Table 4: Legalizing UAVs with regulations as discussed maximized utility.

Factors in Warfare	**Positive Utility**	**Negative Utility**
Civilian casualties	N/A	Loss of human life
Cheaper than aircrafts	Save money	N/A
More lightweight than aircrafts	Less hassle to maneuver	N/A
Strike fear in locals	Dishearten enemy forces	Needlessly scare civilians
Bolder attacks than manned aircrafts	More intense attacks against enemy combatants	May allow freedom to lead to excessive attack force
Can be hacked	Not likely	Intel leak, death of allied troops

This table shows that there are multiple benefits to using drones for warfare, but the most daunting cost of its use is the trauma and death of civilians. The benefits seem to outweigh the costs in this analysis so drone use in war could potentially have a positive impact from a utilitarianism standpoint. While duty ethics is perhaps not the most suited to evaluate the ethics of using UAVs for warfare in general, this framework is able to be applied effectively to more specific aspects of using these machines for war.

Duty ethics is a suitable framework to analyze the ideas of limiting civilian casualties. A useful maxim for this analysis is the lives of civilians should be preserved whenever possible. This maxim would safeguard civilians if it were universal law, preventing many unnecessary deaths. In addition, it treats people as the end rather than the means, which means that it is approved under the reciprocity principle. Using UAVs for warfare would potentially cut the number of civilian casualties due to their efficiency so if this is the case, using UAVs for warfare is to be considered.

When considering the fact that using drones for war would preserve the lives of allied troops, duty ethics can be used to determine whether it is an ethical move. A maxim to be considered is, in the midst of a war, preserve the lives of as many allied soldiers as possible. This can be made universal law because a countrys military wants to minimize their losses. The reciprocity principle is also preserved with this maxim since the lives of the troops are treated as the end. This is apparent because the very purpose of using UAVs for combat is to preserve the lives of the soldiers. As of Dec. 28, 2017, 33 soldiers in the United States military died in a warzone that year (Bergengruen, 2017). If UAVs were implemented, there will be less need to endanger the lives of soldiers.

7.3 Proposed Solutions

While using UAVs for warfare has multiple advantages, there are also dangers that need to be considered when implementing drones for this use. When using drones for this purpose, it is important to safeguard against having equipment on the drone stolen and leaking intel to enemy forces. As noted in the previous section it is important to base these recommendations on a viable ethical framework.

On a practical level, it is important to preserve valuable equipment by not having the UAV stolen. Having a UAV captured by the enemy could result in the loss of weapons, cameras, and parts that are used to operate drones. One of the most pressing dangers of having the UAV stolen is that cutting-edge warfare tactics and technology that the drone uses can be stolen for enemy use.

In other words, if UAVs are used for combat or scouting using groundbreaking tactics or technology, the enemy forces could adopt these methods and tools for their own use in the war. This is clearly dangerous so it is imperative to ensure this does not happen. Two ways to prevent this is by not using cutting edge technology on UAVs or taking extra precautions to ensure that the drone does not get stolen. Another downfall to having the drone get stolen is that it could then be hacked, which could result in a leak of crucial military information.

It is also very practical to prevent the leak of intel to enemies. To prevent having intel leaked to the opposition, it is important to safeguard the drone against getting hacked. Just like how a drone can have its items taken if it were stolen, its data could be compromised as well. This is therefore another reason to prevent the enemy from stealing the allied forces drones. In addition, the UAV must be controlled by the military by use of a secure network connection. If the drone were to connect to an unsecured connection at some point, the intel that the drone has will be made vulnerable.

The military has a duty to do whatever possible to prevent these dangers from happening because if they do not, the lives of the soldiers will be endangered. The previous section notes the decrease in civilian casualties when drones are used for strikes compared to when soldiers carry out a strike on enemy combatants. A deontological ethics analysis arrived to the conclusion that drone use in war could be beneficial because of the decrease in civilian deaths. Therefore, if UAVs were to be used in war it would be necessary to ensure that regulations are in place that prevent civilian fatalities. Some of such regulations would include having a process where most drone strikes must be approved by the higher-ups in the military with civilian life as a great priority.

Chapter 8

Conclusion

Groundbreaking, lightweight, swift, efficient, and practical; these are just a few terms that describe UAVs. These terms may all be accurate descriptors, but they do not make UAVs exempt from susceptibility to corruption and abuse. Some criminal acts that are enabled by UAVs are drug smuggling, stalking, weaponized attacks, and privacy infringement. With this in mind, it is pivotal that viable ethical frameworks are used to place restrictions on UAV use for civilian surveillance, lest UAVs cause modern society to be transformed into a nightmarish dystopia.

The derived regulations in this report were created using ethical frameworks that primarily consisted of virtue ethics, Kantianism, and utilitarianism. These frameworks made it possible to safeguard UAV use against immoral practices, which would greatly benefit the collective interest of society. This is not to say that all negative impacts of drone use will be eliminated by these restrictions, but they surely mitigate these harmful results. The analysis of UAVs occurred by dividing applications into three primary categories: surveillance, service, and warfare. UAVs are already used for these applications to different extents, but their use is expected to grow in the near future.

UAVs are already used abundantly in todays society, but in the years to come, it is inevitable that UAVs will be used more widely for civilian surveillance applications. The recent past has shown that the contemporary individual is becoming more and more dependent on technology. This fact is exemplified by the prevalence of iPads, smartphones, laptops, and televisions in the modern world. If history repeats itself were a law that governs this universe, UAVs are prone to become more immersed in todays society.

In the surveillance aspect, the projected outcome is that they will be more widely used. However, it cannot be implemented without overcoming the inevitable challenges that come with such a lofty goal. For these initiatives to be made possible, existing laws must be retouched to account for privacy and security concerns. In addition, it would be desirable to use UAVs for this application in an organized way to minimize collateral damage. Of the various surveillance applications, fire monitoring is likely to be the first area where UAVs will be more widely used for assistance. This is because fire monitoring has a more direct impact on society as a whole than the other surveillance applications. If it were to be used for ecological and geological mapping and pollution, it would almost certainly take much longer to be implemented due to the lack of pressure for it to be used in this way. However, UAV use for infrastructure could start earlier than the other two applications because construction has been very key in todays society, which thrives on industrialization.

UAVs are projected to be used more widely in the near future with regard to service applications. This initiative has in fact already begun in the area of e-commerce. In areas of rural China, such as the village called Zhangwei, a company called jd.com has already started using UAVs to deliver online purchases (Economist, 2018). Similarly, Amazon intends to use UAVs to deliver packages as early as 2020 (Economist, 2018). With the recent spread of this use for drones, they will continue to become increasingly prevalent for delivery applications when Amazons competitors decide to use drones for this purpose and there arrives a greater demand for packages to be delivered in this way. Similarly, UAVs are predicted to grow in their use in the areas of journalism and healthcare primarily to preserve peoples lives. Journalists will no longer need to go to hazardous areas to report a story when UAVs are applied to this field. Patients will be able to get their treatment more quickly than it would have been received with the use of UAVs in this way. There is a present demand for UAVs to be used in the preservation of human life, but there is a lack of financial gain to be earned when UAVs are used for this purpose so this implementation would likely not happen until much later than it will for e-commerce.

With regard to warfare, UAVs are already widely used extensively. There are countless news stories that report news of another drone strike that has occurred. This method of warfare is especially applied in the Middle East. Since it is still a relatively new innovation, UAVs are predicted to be used in a weaponized manner more and more as time goes on. The end of this matter is that UAVs are expected to be used more frequently as time progresses, but there must be ethical boundaries in place to prevent UAV use from becoming a hazard to society.

List of Figures

List of Tables

References

Alvear et al, August 7, 2017, Using UAV-Based Systems to Monitor Air Pollution in Areas with Poor Accessibility: Journal of Advanced Transportation, v. 2017, 14 p., [https://www.hindawi.com/journals/jat/20 Accessed July 18, 2018].

Averett, N., July, 2014, Drones Take Off as Wildlife Conservation Tool: Audubon, [https://www.audubon.org/maga august-2014/drones-take-wildlife-conservation-tool, Accessed July 6, 2018].

Barrett, D., May 18, 2015, Burglars use drone helicopters to target homes: Telegraph, [https://www.telegraph.co.uk use-drone-helicopters-to-identify-targe-homes.html, Accessed July 6, 2018].

Bergengruen, V., December 28, 2017, These US Troops Were Killed In Combat During Trumps First Year In Office: BuzzFeed News (Online). [https://www.buzzfeednews.com/article/verabergengruen/these-us-troops-were-killed-in-combat-during-trumps-first#.qfkDrQelVW]

Bhatt et al., 2018, Targeted Applications of Unmanned Aerial Vehicles (Drones) in Medicine: Telemedicine and e-Health, v. 0.

Bittel J., August 10, 2017, Pollution is Turning Sea Snakes Black – for a Surprising Reason: National Geographic, [https://news.nationalgeographic.com/2017/08/sea-snakes-color-pollution-environment-oceans/, Accessed July 18, 2018].

Branson-Potts, H., December 14, 2017, L.A. Fire Department used drones for the first time during Skirball fire: Los Angeles Times, [http://www.latimes.com/local/lanow/la-me-ln-lafd-drone-skirball-fire-20171214-story.html, Accessed July 7, 2018].

Brisson-Curadeau et al, December 20, 2017, Seabird species vary in behavioural response to drone census: Scientific Reports, v. 7, [https://www.nature.com/articles/s41598-017-18202-3, Accessed July 22, 2018].

Bryce, E., March 19, 2015, How to Count a Thousand Birds (Or More): Audubon, [https://www.audubon.org/news/how-count-thousand-birds-or-more, Accessed August 14, 2018]. Burke, D., July 17, 2017, 'Unethical' high-tech hunters using drones to find prey: CBC News, [https://www.cbc.ca/news/canada/novascotia/drones-hunting-ethics-deer-moose-bear-technology-1.4207616, Accessed July 22, 2018].

Callam, A., 2010, Drone Wars: Armed Unmanned Aerial Vehicles: International Affairs Review, v. 18. [http://www.iar-gwu.org/node/144, Accessed August 6th, 2018]

Cart et al, July 29, 2008, Air tanker drops in wildfires are often just for show: LA Times, [htt p://www.latimes.com/local/la-me-wildfires29-2008jul29-story.html, Accessed August 14, 2018].

Choi, C., October 27, 2017, Fighting Air Pollution on the Fly: Inside Unmanned Systems, [http://insideunmannedsy air-pollution-fly/, Accessed July 18, 2018].

CNN, October 18, 2017, CNN Receives Breakthrough Part 107 Waiver for Operations Over People: CNN.

Cook, K.L.B., 2007, The Silent Force Multiplier: The History and Role of UAVs in Warfare: 2007 IEEE Aerospace Conference, Big Sky, MT, pp. 1-7.

Cruz et al, June, 2016, Efficient Forest Fire Detection Index for Application in Unmanned Aerial Systems (UASs): Sensors, v. 16, no. 6.

DroneView Technologies, June 21, 2016, Drones and the Photogrammetry Process: Understanding the Basics, [https://www.droneviewtech.com/blog-and-news/2016/6/20/drones-and-the-photogrammetry-process-understanding-the-basics, Accessed August 17, 2018].

Evangelista, B., May 12, 2017, Fire, Police Drones Caught Between Public Safety and Privacy Concerns: Government Technology, [http://www.govtech.com/policy/Fire-Police-Drones-Caught-Between-Public-Safety-and-Privacy-Concerns.html, Accessed July 22, 2018].

Federal Aviation Administration, July 24, 2018, Getting Started: Federal Aviation Administration.

Federal Highway Administration, February 1, 2017, Work Zone Mobility and Safety Program: U.S. Department of Transportation, [https://ops.fhwa.dot.gov/wz/resources/publications/fhwahop12005/sec5.htm Accessed August 14, 2018].

F550 ARF KIT + Landing Gear + Naza M-Lite + GPS: DJI, [https://store.dji.com/product/f550-naza-m-lite-gps-landing-gear, Accessed July 18, 2018].

Feeney, W., July 15, 2015, Natural Selection in Black and White: How Industrial Pollution Changed Moths: The Conversation, [http://theconversation.com/natural-selection-in-black-and-white-how-industrial-pollution-changed-moths-43061, Accessed July 18, 2018].

Gibbens, S., October 10, 2017, Birds That Turned Black from Pollution – What That Teaches Us Today: National Geographic, [https://news.nationalgeographic.com/2017/10/birds-air-pollution-soot-black-carbon-spd/, Accessed July 18, 2018].

Gynnild, A., 2014, The Robotic Eyewitness: Digital Journalism, v. 2, pp.334-343.

Hartmann, K. and Giles, K., 2016, UAV Exploitation: A new domain for cyber power: 2016 8th International Conference on Cyber Conflict, Tallinn, pp. 205-221.

Hajiyev et al, 2015, State Estimation and Control for Low-cost Unmanned Aerial Vehicles: Switzerland, Springer Cham, 239 p.

Herring, D., May 29, 1998, NASA Demonstrates New Technology for Monitoring Fires from Space: NASA Earth Observatory, [https://earthobservatory.nasa.gov/Features/Fire, Accessed July 18, 2018].

Hodgson et al, March 17, 2016, Precision wildlife monitoring using unmanned aerial vehicles: Scientific Reports, v. 6, no. 22574, [https://www.nature.com/articles/srep22574, Accessed July 6, 2018].

Hodgson et al, February 13, 2018, Drones count wildlife more accurately and precisely than humans: British Ecological Society, v. 9, no. 5, pp. 1160-1167, [https://besjournals.onlinelibrary.wiley.com/doi/full/10. 210X.12974, Accessed July 6, 2018].

Holton et al., 2015, Unmanned Aerial Vehicles: Journalism Practice, v. 9, pp. 634-650.

Johnson, S., January 6, 2018, A.I. "predator" drones can now spot and track illegal poachers: big think, [https://bigthink.com/stephen-johnson/ai-predator-drones-can-now-spot-and-track-illegal-poachers, Accessed July 22, 2018].

Jordan, B.R., January 25, 2015, A birds-eye view of geology: The use of micro drones/UAVs in geologic fieldwork and education: GSA Today, v. 25, no. 7, pp. 42-43, [http://www.geosociety.org/gsatoday/archi 5173-25-7-50.htm, Accessed July 7, 2018]. Junaid et al, June 13, 2017, Autonomous Wireless Self-Charging for Multi-Robot Unmanned Aerial Vehicles: Energies, v. 10, no. 6, [http://www.mdpi.com/1996 1073/10/6/803/htm, Accessed July 21, 2018].

Lada, B., October 15, 2017, Devastating California Wildfires Predicted to Cost US Economy $85 Billion; Containment May Take Weeks: AccuWeather, [https://www.accuweather.com/en/weather-news/devastating-california-wildfires-predicted-to-cost-us-economy-85-billion-containment-may-take-weeks/70003000, Accessed July 18, 2018].

Landhuis, E., March 10, 2018, Medical Cargo Could be the Gateway for Routine Drone Deliveries: NPR.

Le Page, M., December 8, 2016, Fish Adapt to Pollution Thousands of Times Lethal Levels: New Scientist, [https://www.newscientist.com/article/2115635-fish-rapidly-adapt-to-pollution-thousands-of-times-lethal-levels/, Accessed July 18, 2018].

Lohn, A.J., 2017, Whats the Buzz? City-Scale Impacts of Drone Delivery: RAND Corporation, [https://www.rand.org/content/dam/rand/pubs/research_reports/RR1700/RR1718/RAND_RR1718.pdf, Accessed August 13, 2018].

McNeal, G., November, 2014, Drones and aerial surveillance: Considerations for Legislatures: Brookings, [https://www.brookings.edu/research/drones-and-aerial-surveillance-considerations-for-legislatures/, Accessed July 22, 2018].

Matrice 100: DJI, [https://store.dji.com/product/matrice-100, Accessed July 18, 2018].

Merino, L., Caballero, F., Martinez-de-Dios, J.R., and Maza, I., 2010, Automatic Forest Fire Monitoring and Measurement using Unmanned Aerial Vehicles: VI International Conference on Forest Fire Research, [http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.722.7608&rep=rep1&type=pdf

Accessed July, 7 2018].

Meuse, M., July 22, 2016, B.C. government bans drones-assisted hunting: CBC News, [https://www.cbc.ca/news/ca

columbia/bc-drone-hunting-1.3691426, Accessed July 22, 2018].

Mn DOT Research, October 11, 2017, Cost-Effective Strategies for Repairing Grout in Post-Tensioned Bridges: Mn DOT, [https://mntransportationresearch.org/tag/bridge/, Accessed August 17, 2018].

Mulero-Pazmany et al, June 21, 2017, Unmanned aircraft systems as a new source of disturbance for wildlife: A systematic review: PLoS ONE, v. 12, no. 6, [http://journals.plos.org/plosone/article?id=10.1371/j

Accessed July 22, 2018].

MultiPix imaging, 2018, What is unique abour NIR (Near-Infrared) cameras?, [https://multipix.com/knowledgebas

is-unique-about-nir-near-infrared-cameras/, Accessed August 13, 2018].

Nature Communications, v. 9, no. 409, [https://www.nature.com/articles/s41467-017-02411-5.pdf, Accessed August 13, 2018].

Northrop Grumman, 2018, Global Hawk - 20 Years of Flight: Northrop Grumman. [http://www.northropgrumman

Accessed August 6th, 2018]

Nuwer, R., March 13, 2017, High Above, Drones Keep Watchful Eyes on Wildlife in Africa: NY Times, [https://www.nytimes.com/2017/03/13/science/drones-africa-poachers-wildlife.html], Accessed July 22, 2018.

Phantom 4 Pro V2: DJI, [https://store.dji.com/product/phantom-4-pro-v2?vid=43151, Accessed July 18, 2018].

Poel, Ibo , and Lamber M. M. Royakkers. Ethics, Technology and Engineering: An Introduction. Oxford: Wiley-Blackwell, 2011. Print.

Piras et al, September 14, 2016, Detailed geological mapping in mountain areas using an unmanned aerial vehicle: application to the Rodoretto Valley, NW Italian Alps: Geomatics, Natural Hazards and Risk, v. 8, no. 1, pp. 137-149, [https://www.tandfonline.com/doi/pdf/10.1080/19475705.2016.122522 Accessed July 7, 2018].

Reyes, E.A., June 20, 2017, L.A. Fire Department could soon seek federal permission to fly drones: LA Times, [http://www.latimes.com/local/lanow/la-me-ln-fire-drones-20170620-story.html, Accessed July 22, 2018].

Saalfield, P., January, 2012, The Biology of Right and Wrong: Harvard Magazine, [https://harvardmagazine.com/20 biology-of-right-and-wrong, Accessed August 17, 2018].

Sandbrook, C., October 27, 2015, The social implications of using drones for biodiversity conservation: Ambio, v. 44, no. 4, pp. 636-647, [https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4623858/, Accessed July 6, 2018].

Satellite Imaging Corporation, 2017, WorldView-4 Satellite Sensor (0.31m), [https://www.satimagingcorp.com/sate sensors/geoeye-2/, Accessed August 16, 2018].

Schuckman, K., and Dutton, J.A., 2018, Elevation Data Collection: Penn State College of Earth and Mineral Sciences, [https://www.e-education.psu.edu/geog480/node/511, Accessed July 21, 2018].

Schuckman, K., and Dutton, J.A., 2018, Elevation Data Products: Penn State College of Earth and Mineral Sciences, [https://www.e-education.psu.edu/geog480/node/512, Accessed July 21, 2018].

Scott, J. and Scott, C., 2017, Drone Delivery Models for Healthcare: 50th Hawaii International Conference on System Sciences.

Stolaroff et al, March 8, 2018, Energy use and life cycle greenhouse gas emissions of drones for commercial package delivery:

Szentpeteril et al, October 6, 2016, Drones (UAVs) in mining and exploration. An application example: Pit Mapping and Geological Modelling: MGEI 8th Annual Convention, [https://www.researchgate.net/pu Accessed July 7, 2018].

Tate, E., May, 1998, Remote Sensing With Digital Orthophotos, [http://www.ce.utexas.edu/prof/maidment/grad/t Accessed July 22, 2018].

Tseng et al, January, 2017, Autonomous Recharging and Flight Mission Planning for Battery-operated Autonomous Drones: arXiv, v. 1, no. 1, 25 p., [https://arxiv.org/pdf/1703.10049.pdf, Accessed July 21, 2018].

Tucker, P., May 3, 2018, A Criminal Gang Used a Drone Swarm to Obstruct an FBI Hostage Raid: Defense One, [https://www.defenseone.com/technology/2018/05/criminal-gang-used-drone-swarm-obstruct-fbi-raid/147956/, Accessed July 6, 2018].

USGS, 2018, U.S. Geological Survey: USGS, [https://www.usgs.gov/, Accessed July 18, 2018].

Wall, T. and Monahan, T., 2011, Surveillance and violence from afar: The politics of drones and liminal security-scapes: Theoretical Criminology, v. 15, pp. 239-254.

Winter, J., February 3, 2018, What Would Happen if Terrorists Attacked the Super Bowl With Drones?: Foreign Policy, [https://foreignpolicy.com/2018/02/03/what-would-happen-if-terrorists-attacked-the-super-bowl-with-drones/, Accessed July 22, 2018].

Yakowicz, W., March 21, 2016, Amazon Has Spend Nearly $10 Million Lobbying for Drone Delivery: Inc, [https://www.inc.com/will-yakowicz/amazon-spends-millions-lobbying-drone-delivery.html, Accessed in August 17, 2018].