

# **Drone Technology and Applications**

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# **Table of Contents**

1 Executive Summary	
2 Introduction	
3 Types of Drones	5
4 Market Analysis	6
5 Application of Drones	
5.1 Agriculture	
5.2 Transportation	
5.2 Aerial photography	
6 Regulations	
7 Conclusion	
8 References	

# List of Tables

1 Summary list of application areas for drone technology	9
2 Classification of UAVs	
3 FAA Requirement and Rules for Two Types of Flying Purposes	

# List of Figures

1 Predicted Value of Drones by Industry	6
2 Direct Economic Impact in the UAV Industry	7
3 US Commercial Drone Market by Application	
4 A schematic picture demonstrating uses of agricultural drones in future farms	11
5 Use of drones by Amazon for delivering packages to customers	
6 Ehnag 184 drone at the World Government Summit 2017 in Dubai	14
7 Word Drone Market Revenues for Logistics and Retails Application Segment .	
8 A camera drone flies over a volcano for media purposes	

## **1 Executive Summary**

Drones, also named as unmanned aerial vehicles (UAVs), are becoming increasingly popular around the world. The objective of this paper is to understand different type of drones and its applications. This paper focuses mainly in agricultural, transport and aerial photography sector. It explores the UAV market, challenges and future opportunities in these three sectors. Regulations play an important role in the growth of UAV. Therefore, Regulations are also explored in this paper.

# **2** Introduction

Drones are unmanned aerial vehicle or unmanned aircraft system. They can fly autonomously without an onboard pilot. It is referred to as remotely piloted aircraft by International civil aviation organization. The launch of drones is by an automatic system or external operator on the ground. It uses GPS to navigate flight path. They are controlled through software controlled flight plans in their embedded systems in conjunction with onboard sensors and GPS [1].

The payload is below the structure of the UAV body. It consists of equipment's based on the use target of the UAV. It consists of photo and video camera, sensors for data collection, GPS, navigation sensors, communication equipment's and other equipment's required for specific use target. The size of the drone, flight capabilities and ability to withstand extreme environments enables them to survey environments that may not be accessible otherwise. It helps them to capture information from a distance or altitude. It enables them to capture information that could not be monitored because of height and angles.

Unmanned aerial vehicle were used in military for weapon platforms, anti-aircraft target practice and intelligence gathering. Currently they are used for traffic and weather monitoring, search and rescue, surveillance, personal drones, photography, videography, journalism, agriculture and delivery service [1].

Drone surveillance is used to gather information about specific targets. Drones journalism is used to record events that may go unreported due to risk of personal injury of reporters [2]. Agricultural companies use drones to monitor land and corps. Energy companies use drones to survey power lines.

In 2012, Robotics Inc specialized in hobbyist drones and marketed to photography, film companies, construction, telecom and public safety companies [1]. In 2013, Amazon announced to use drones

for delivery service.

There is a tremendous growth in commercial and personal drones although there are number of safety concerns. Federal aviation administration requires authorization for commercial drone operation. On the other-side there are also risks related to damage or loss of drones.

# **3** Types of Drones

Drones are built with features and design specific to the application [3]. Below are different types of drones used for different purpose:

- **Quadcopters**: Quadcopters are mini-drones. They are equipped with FPV. It has 4 rotors in square pattern. Quadcopters are made with battery and can be recharged when needed. It is a short-range drone.
- **GPS Drones**: GPS drones work properly when the GPS signal is good. It will return to its location when it runs out of battery. It is a mid-range drone.
- **RTF Drones**: Ready to fly drones are for beginners. Drone can be started using once the battery is charged.
- **Trick Drones**: Trick drones are also for beginners to understand drones. It is designed to be used as a toy. Drones are also built with small cameras.
- Helicopter Drone: Helicopter drone has a single rotor. It can be in air for a long period. It can easily land at any place. It has landing bars and it is like real helicopter. It is not fast and agile as the other drones.
- **Delivery Drone**: Delivery drones have an anchor or basket at the bottom to carry materials. These drones are used by the retail industry to deliver materials. This drone is useful for delivering materials at remote location and mountain regions which are not easily accessible. It can carry 20 to 30 pounds.
- **Photography Drone**: Drones are built with cameras. Drones used for photography and videography are built with HD-quality camera. The lens is covered with guards so that it does not get damaged during extreme weather conditions. Smart phone or tablet can connect with the cameras in the drone to view the pictures. License depends on the size of the drone.
- **Racing Drone**: Racing drones can fly 40 to 60 miles per hour. Racing drones have stronger engines compared to other drones. Wind will not have much impact on racing drones.
- **Gas Powered Drone**: Gas powered drone run using gas. These drones are stronger and fly for a longer time. They are heavier compared to other models.

- Nitro Powered Drone: Nitro fuel is used to run these drones. Engine is smooth because it brings oxygen in combustion process. It is lighter in weight. Nitro powered drone can be converted into a gas-powered drone.
- Endurance Drone: Endurance drones are large drones. It can fly for a long time and above 400-foot height. License is required to operate this drone. It may work with battery or gas or nitro fuel. They are usually reserved for military purpose.

# 4 Market Analysis

The demand for military drones is higher compared to commercial drones. Commercial drones are catching up. Government organization across the globe are using drones in applications such as infrastructure, environmental analysis, research, disaster management and many other activities. Retail companies are working on using drones to deliver products within a short span of time.

The use of drones has been banned by US Federal aviation administration and European aviation safety agency. Human safety and managing air traffic are the reasons for drones being banned in logistics sector. Federal aviation administration allows drones that weigh 55pounds to fly during the day below 500 feet in the air.

Global drone market is expected to reach \$25 billion by the end of 2023 with a CAGR (Compound Annual Growth Rate) of 18.2%. Number of commercial drones sold in 2015 is almost \$4 million. The number of units expected to be sold in 2023 is \$18 million [4]. As below Figure 1 showing, the market value of drone powered solution is estimated \$127 billion in total [5].



Figure 1: Predicted Value of Drones by Industry [5]

Currently, north America leads the global drone market with its increasing application and production of drones. Europe is said to be the most attractive market in terms of profit. As for Canada, Drones are used mainly for atmospheric monitoring and oceanographic research. Figure 2 shows the estimated direct economic impact from the UAV industry in US [4].



Figure 2: Direct Economic Impact in the UAV Industry [4]

Drones are used in agricultural sector for crop monitoring. It increases the yield. This emerge as a dominant application sector over the forecast period in the US commercial drone market. Facebook and Google are planning to use solar powered UAVs to provide internet access in remote areas. In the retail sector, Amazon has been planning to use drones to deliver products. UAVs are used in mapping, law enforcement, high altitude imaging, wild life patrolling, forest fire monitoring. In the media and entertainment sector, few production companies have been approved by FAA to use drones on film sets. Other applications include environmental monitoring, natural hazard research, soil moisture imaging. The estimated market size to 2020 by applications for US market is shown in Figure 3.



Figure 3: US Commercial Drone Market by Application [6]

PricewaterhouseCoopers LLP said global market for commercial drone applications will reach \$127 billion by 2020. The growth in commercial drones is a result of growing demand for drones and drone generated data in commercial applications. It is used in executing high risk tasks. Reduced capital cost, low operational cost and technology maturity increases the opportunities in the commercial sector by expanding the applications [6].

## **5** Application of Drones

#### Classification

Drones can be classified based on size, type of application, range and endurance [7].

In this paper, drones have been classified based on the type of application. It has been classified under two main categories, military and non-military. This paper focuses on specific uses of non-military drones.

#### Applications

Drones have expanded from the military sphere into the other applications. Practical use of drone technology range from applied sciences to media and recreational purposes and is expanding rapidly. This unique and adaptable technology allows professionals in different fields to work more efficiently and at a rapidly decreasing cost.

Universities and professional institutions are also focusing on developing and promoting emerging drone technology. Drones have a wide variety of applications in different fields. Table 1 shows a

list of potential uses of drone technology in many fields.

Table 1: Summary	y list of application :	areas for drone technology
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Pipeline Monitoring	Power line Monitoring
Disaster Relief	Watershed planning
Forest and Land Survey	Environmental Survey
Forest Fire Management	Critical Infrastructure Protection
Mineral Surveys	Offshore Monitoring
Atmospheric and Ocean Studies	Deforestation and Wildlife Conservation
Ice Flow Monitoring	Border Integrity
Pollution Detection	Population Control and Monitoring
Agriculture	Crime Scene Surveys
Medical Services	Counter Narcotics
Search and Rescue	Security
Communication	Traffic Monitoring
Smoke Stack Inspection	Transportation and Cargo Services
Cinema and TV applications	News Services
Recreational Purpose	Aerial Videography and Photography
Tourism	Mapping
Emergency Services	Military

In this report, we reviewed three broad and major applications of drone technology, namely agriculture, aerial photography and transportation.

# **5.1 Agriculture**

As the global demand for agricultural products are increasing, farmers need to find efficient methods to increase productivity. Drone technology has helped farmers with agricultural activities and farm management. Farmers and agricultural scientists use drones to study crops, to monitor irrigation patterns, and improve management and yield. Farmers use drone technology to improve efficiency, to increase their crop production and to monitor crop growth at lower cost [8].

Purpose of drone technology in agricultural sector:

- To measure, observe, and respond to variations found in crops
- To check storm damage
- Crop and yield monitoring
- Chemical applications and spraying
- Land management
- Crop & livestock inventory management
- Forest and land survey

Agricultural drones increase yield and decrease crop damage [9]. Drones help farmers to view irrigation problems, soil variation and fungal infestations from air. Drones takes images and captures data to highlight differences between healthy and distressed plants. It can also be used to monitor crops every week or day or hour [9]. "Precision drones now serves farmers in 20 U.S. states and Canada" [10]. For instance, some farmers set up video drones for crop management purpose from a distance [10].

Figure 4 shows a schematic view of what the farm of the near future could look like [11]. The picture below outlines the importance of emerging drone technology in the future of farms and their productivity.



Figure 4: A schematic picture demonstrating uses of agricultural drones in future farms [11]

#### Market

In the agricultural sector drone is said to boom the crop yields. It detects the areas in the field where crops are failing and sprays nutrients or pesticides. It quickly gathers and analyzes data in the field. It is used in the analysis of soil and drainage, crop health assessment. Market value in agriculture industry is estimated \$32.4 billion [5]. It is among the top revenue generators in the commercial drone industry. Tractica forecasts agricultural robot sales to reach 1 million units in 2024 from 33000 units in 2015. Revenue is also expected to grow from \$3 billion in 2015 to \$73.9 billion in 2024 [12].

#### Challenges

One of the main obstacle in the agricultural sector is the large farm land and low efficiency in crop monitoring tasks. The unexpected changes in global weather also affect the agricultural sector. Drones can take pictures with great resolution down to a few cm per pixel which is much higher than satellite images which were used before. Although few drones can fly irrespective of the weather condition, the image quality is affected because of poor weather conditions. There are lot of advantages of using drones in agricultural sector but the new concern is the type and quality of data obtained from drones. Thus, this would increase the need of advanced sensors and camera. To reduce the difficulties for farm personnel's in operating drone system, the design of the drone control interface should be simple. In that case training farm personnel's in using drones should be easy [8].

#### **Future opportunities**

The use of drone technology is expected to grow immensely in agricultural field with a wide range of applications which can help to improve precision agriculture. As of today, drones cannot communicate with agricultural equipment's, therefore one of the biggest opportunity in future is connecting drones with agricultural equipment's. Drones have ability to fly over the fields and take high resolution images which can be sent to the cloud and it is also made available to the customers. This data can further be used to analysis. Data can be used to select the precise location that the farmer wants to work. This can help with tasks such as inputting seeds, fertilizers, pesticides which needs to be applied to field accordingly [13].

Some other areas drones can prove to be beneficial in the future deals with inspections and performing minor detail tasks. One of way drones can help in farming is through its ability to fly and look under leaves. The issue plants faces are the accumulation of pests and fungus which takes hold underneath the leaves which are not immediately visible. Thus, drones can develop functionalities by having sensors that can help see through the foliage which can help sense bugs, fungus, pests and others which are damaging the plants.

Another way drones will help agriculture is by developing functionality that can help to pollinate like bees. Although insects pollinate plants, it also results in outbreak of disease and new predators can reduce their numbers. Therefore, in such case, drones can be useful if it can develop maneuverability to fly inside flowers to gather pollen and deposit into the plants. Also, drones can also perform occasional pruning to ensure the crops develop healthy by chopping dead parts of the plants [14].

It is predicted in future, drones might involve fleets or swarms of autonomous drones which can help tackle agricultural monitoring tasks collectively. Also, hybrid aerial ground drone can help to collect data and perform variety of other tasks [15].

# **5.2 Transportation**

Another major application of drone technology is in the field of transportation. Drone technology can be used at different stages in the transportation sector. The main goal of using drones is to meet

the desires and needs for the movement of people, delivering smart parcels and expanding some services. Drones can be used to deliver small packages, pizzas, letters, medicines, beverages etc. at short distances. Transportation drones will help some countries to improve and expand different type of services in urban or in a remote rural area, because the need is high and the risk is low. Major abilities of drones in the transportation sector are as follows:

- Urban delivery systems for small parcels, provided by Amazon, google, DHL, etc.
- Delivering medical supplies to inaccessible regions and patients
- Transportation of samples, medicine and critical supplies between health facilities
- Support transportation by providing better traffic surveillance and traffic management
- Moving people by applying new technology called "Drone Taxis"

The goal of some companies like Amazon or postal services is the usage of drones to deliver small packages and parcels to people who are living in places that are hard to reach. In fact, Amazon has already begun preliminary testing for delivering small goods in rural areas and has seen positive results. Figure 5 illustrates the use of drones for delivering parcels.



Figure 5: Use of drones by Amazon for delivering packages to customers [16]

This emerging technology will aid rescue organizations in quickly delivering medical supplies in the field and on demand. Timothy Amukele said drones also can help in some regions to improve distribution of blood products in rural areas where they lack easy access to hospitals or clinics [17]. In the field of non-military surveillance monitoring, drones also are used to provide better traffic surveillance and traffic management.

Apart from uses of drones for delivering goods and packages, at CES 2016, a Chinese company, Ehang, announced a drone designed for personal transportation. This company revealed a new drone called Ehang 184 that has space for seating a single passenger who weighs less than 220 pounds and can carry a small suitcase. This company introduced Ehang 184 as a safe and Eco-friendly low altitude vehicle that provides a medium-short transportation service [18]. In February 2017, this company and the Dubai Roads and Transportation Authority (RTA) announced a joint effort "to build the world's most intelligent transportation system" by using Ehang 184 as an aerial taxi in Dubai [19]. A picture of this vehicle shown in Figure 6.



Figure 6: Ehnag 184 drone at the World Government Summit 2017 in Dubai [19]

Therefore, transportation drones play a major role in the logistics industry and short distance transportation services in near future.

#### Market

In the transport industry, drones are being used for last mile services for delivering in the mountain regions. Drones are used for delivery of goods and medical logistics. In Switzerland, postal carriers have been replaced with drones to deliver in regions that are difficult to reach [20]. Walmart, world's largest retailer requested U.S. regulators for permission to test drones indoor. They plan to improve its distribution system. It also requested Federal Aviation Admission to grant permission

for testing the use of drones in deliveries to its customers at home and at Walmart facility. Amazon launched a video to show how they would use drones to deliver packages [20]. UPS delivery using drones saves \$50 million when delivery by road is reduced by one mile per driver every day. Rural delivery is expensive and is expected to be reduced by the use of drones. Market value of drone in transport industry is estimated \$13 billion [5]. In 2015, drone market revenue in logistics and retail is \$7.6 million which is less than 0.5% of the total market revenue. Market revenue in logistics and retail is said to be less than 1% of total market revenue between 2016 and 2020 [21]. The barriers for drone in logistic sector is legislation, flight safety, package size constraints, technology challenges, cost of drone delivery per time, cost of pilots and drone maintenance cost.



World Drone Market Revenues from "Logistics & Retails" Application Segment, 2014-2020

Figure 7 - Word Drone Market Revenues for Logistics and Retails Application Segment[21]

#### Challenges

There are some barriers for drone in this application. First of all, the related legislation is the biggest challenge. For example, in US, Federal **Aviation Administration** (FAA) requires the drone operation must be in the sight of the drone pilots. The size of the delivered item is limited to the drone's cargo box and under the weight limits (typically less than 5 kilograms) [22]. Also, the

new air traffic management system needs to take care of the integrating with manned aviation air traffic management systems. Because it might often be used in metro area, there are potential problems of the crowded frequency spectrum and related security issues, including jamming, hacking and spoofing. Furthermore, to ensure the safety up in the air, the demands for new technologies for sensors and collision avoid system are increased. This also increases challenges for the real-time computing performance to capture, process, transmit and store large size of data at the same time in the mobilized processing environment.

#### **Future opportunities**

Transportation is yet another field which can prove drones to be useful and beneficial with new capabilities. One way drones will help is by decreasing the need of helicopters. Drones can help conduct all the operations which had been previously performed by helicopter with a cheaper and faster pace.

Apart from helicopters, drones will also help in Airline services. The airline services will adopt drones to diversify their business and build their own drone crew which can help the flyers with their requests and needs. Drones helping the flying services, will also take over the current air transportation facilities as well. Currently, the focus is to transport humans by drones. The team in Dubai is already working on this implementation.

Another future travel opportunities drones will take over is through its application of delivery services such as foods, goods, medical services etc. Amazon.com for example, has plans to implement 30-minute package delivery services with new drones known as "Amazon Prime Air." As of now, Amazon's Prime Air development centers are in the U.S. the U.K, Australia, and Israel, and is testing more than a dozen prototype drones in multiple international locations.

Furthermore, another facility known as Alphabet's "Project Wing" team began using drones to deliver Chipotle burritos on campus of Virginia Tech - within a controlled environment with FAA regulation approved for drone testing [23].

## 5.3 Aerial Photography

Photography and videography in the past decade has been changing at an ever-increasing pace. Stand-alone cameras improved year after year, which were very much a part of our daily lives. In the past, aerial photography was limited to photographers who access to the expensive equipment. During the previous years, new and advanced technology has revolutionized the imaging industry and greatly impacted the industry by creating new ways for capturing images for different purposes while also lowering the bar to entry for aerial photography and videography using drones.

This emerging technology could enhance aerial photography and videography by providing better resolution, enabling new modalities, or facilitating portability. Sending the camera higher in the sky for better perspective to shoot a landscape is the main benefits of camera drones.

Consumer drones in this field, appeared in 2013 with some models capable of carrying small cameras[24]. Nowadays, using drone technology in imaging is one of the most popular forms of photography and plays an important role in many fields including capturing aerial footage for films and photography and because of reduced costs, the technology is becoming available to a wider audience and is no longer limited to professionals.

Drones have significant advantages in comparison with other methods of capturing images. The main advantages of applying this technology as aerial camera platforms in this industry are as follows [8]:

- Capturing images and footage from the air with a new perspective to explore.
- Give media access to those places that are hard to access.
- Easy to fly with affordable costs in comparison with planes or helicopters for capturing images.
- Easy and safe to capture amazing pictures, footage, and perspectives.

A variety of cameras can be attached to a drone. Low weight cameras equipped with live video output and remote shutter control give the user a better opportunity for taking control of the camera while recording a wide range of images and videos. Drone technology in photography has a wide range of applications but some common applications of this technology in the imaging are as follows:

- Use drones for video surveillance and data collection reduce the time spent collecting data by other means
- Give media access to those places that are hard to reach for capturing aerial footage or photos for film making, news broadcasting and TV applications
- Surveying landscapes for capturing high quality digital images and creating 3D maps

Figure 8 shows an example of using a camera drone over a volcano for media purpose which are typically hard to access.



Figure 8: A camera drone flies over a volcano for media purposes [25]

#### Market

In the recent day's consumer drones are used for taking photos and videos. The demand increases when the people see the photos or videos taken using drone. In the film industry, drones are being used for generating special effects, photography, videography, advertising and entertainment. This industry is the primary driver in the consumer drone market. Drone market by photography has generated \$200 in 2015 and is expected to grow more than 15% by 2020 [26]. Market value of drone in media and entertainment is estimated \$8.8 billion [5].

#### Challenges

When it is related to photos and videos, the privacy concern always comes as the first discussion topic. The privacy scope includes both the private property and the private behavior. When drone technology is used in such application field, the privacy issue is also involved with some related usage problems, such as: how to store the data, what types of data could not be collected and how individual or companies could defend for privacy rights. The challenge is how to find the right balance between the right to the skies and the right to the privacy in this application field. Also, the safety concern of flying in metro area is highlighted especially when it is used for large event activities in metro area. However, privacy related rules of drone's operation are still in a state of flux at federal and state levels. In US, some state laws have introduced criminal penalties for misbehavior usages. The safety guidelines rely heavily on community-based organizations such as Academy of Model Aeronautics whose safety code is the most widely referenced standard in UAV industry [27]. Proper legislation still takes time to prepare and be approved.

#### **Future opportunities**

The use of drones is also growing more in the photography which is helping many different fields such as constructions, wedding, farming, sports and many others. Future opportunities in drones deal with ability for photographers and camera operators to fly and drones to consist of powerful picture taking facility which can help provide clear and enhanced images.

Considering the infrastructure, drones are expected to not only diagnose problems with crumbling, cracks, bridges and building facades, but also repairing them. In the future, the 3D printing technology will also be combined with drone technologies which can help maintain and repair infrastructure as it will help attach 3D printers to drones to produce on site replacement parts for damaged elements of infrastructures.

Future drones are expected to become more and more compact with improved camera quality. Drones are already playing a significant role in photography's related to construction, real estate and wedding [8].

#### **6** Regulations

UAVs offer new ways for commercial enterprises and public operators to increase operational efficiency, decrease costs, and enhance safety. It has significantly increased in number and technical complexity during recent years. However, it does not have a set of standardized design specifications for basic UAV design to ensure the safety and reliability in operation in typical civilian service application [28]. A need is recognized to develop a system of UAV classification and regulation which could be applied globally. However, the process is still undergoing and not yet completed within the USA and Europe. The International Civil Aviation Organization (ICAO), a UN specialized agency, is working with the Chicago Convention on ICAO and global aviation organizations to develop international Standards and Recommended Practices (SARPs) as reference when developing the legally-enforceable national civil aviation regulations. Some countries have already adopted legislation and relevant bylaws to enable operation of small UAV. For example, Canada, Australia and Brazil voted their first regulations for UAV's between 2007 and 2011, UK in 2011, France and USA in 2012. However, these regulations should not be considered as fixed because they would still change along with the new technology development of UAV. The topics to be address would include licensing and medical qualification of UAV' pilot, technologies for detect and avoid systems, frequency spectrum, separation standards from other aircraft, and development of a robust regulatory framework [29].

Before the classification work is officially concluded, the below table could be sued as an interim guidance for a UAV classification group [29].

Category	MTOM (kg)	Aviation Regulation Level
Small UAV	< 20	National
Light UAV	20 to 150	National
UAV	> 150	ICAO, EASA

# Table 2: Classification of UAVs

In the USA, it is the FAA's accountability to develop regulations, policy, procedures, guidance material and training requirements to support safe and efficient UAV operations in the **National Airspace System** (NAS). FAA was amending its regulations to adopt specific rules for the operation of **small** UAVs, sometimes called a drone, in the NAS through a final rule since June 2016. These changes address the classification and the operational limitations of small UAVs. It also regulates the certification of the remote pilots who control the small UAVs on the ground [30]. The FAA set up the UAV operating rules based on the purpose of flying which is flying either for fun (e.g. educational or recreational purpose) or for work (e.g. commercial or business usage). Table 3 shows the requirements and operating rules for these two flying purposes [31]:

Table 3: FAA Requirement and Rules for Two Types of Flying Purposes

	Fly for Fun	Fly for Work
Pilot	No pilot requirements	Must have Remote Pilot
Requirements		Airman Certificate
		Must be 16 years old
		Must pass TSA vetting

Aircraft Requirements	Must be registered if over 0.55 lbs.	Must be less than 55 lbs. Must be registered if over 0.55 lbs. (online) Must undergo pre-flight check to ensure UAS is in condition for safe operation
Location Requirements	5 miles from airports without prior notification to airport and air traffic control	Class G airspace*
Operating Rules	Must ALWAYS yield right of way to manned aircraft Must keep the aircraft in sight (visual line-of-sight) UAS must be under 55 lbs. Must follow community-based safety guidelines Must notify airport and air traffic control tower before flying within 5 miles of an airport	Must keep the aircraft in sight (visual line-of-sight)* Must fly under 400 feet* Must fly during the day* Must fly at or below 100 mph* Must yield right of way to manned aircraft* Must NOT fly over people* Must NOT fly from a moving vehicle*

However, a further step problem is lack of enforcement tools to take control of a misbehavior drone over the air. It is easy to define the related regulations for drones. But if people do not obey them, it is not clear who should and can handle and control it.

# 7 Conclusion

Future of Drones is predicted to be one of the most highly talked subject as it is expanding its technological capabilities into more innovative and helpful uses. Drones will take over almost every possible fields and will help reduce difficulties in complicated tasks and missions along with making lives easier. Drones may fly higher than before and new creative fields of applications such as "guided tours" will start. The predicted market size for commercial applications would be valued over \$127 billion in 2020. However, the related regulation progresses are still slow and vary in different countries with the lack of global standard and authority. However, it is not a blocker for continuing the prosperous development and evolvement.

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