The Market for Drones:

An Analysis

An Interactive Qualifying Project

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Report Submitted to:

RobSense, Sponsor

Professor Joseph Sarkis, Advisor
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Abstract

This study was conducted in order to provide our sponsor company, RobSense, with business recommendations for whether they should expand into the United States as well as if they should pursue a total solution drones-as-a-service (DaaS) business model, or if they should become a niche player in the market and offer hardware products only. To this end, the Interactive Qualifying Project (IQP) was conducted over two terms. During the first term, we researched news articles and economic reports in order to understand the demand for drones within the current economy. We made note of related documents such as drone flight regulations that provided more information concerning modern applications of drone technology. During the second term, we interviewed organizations within industries related to drone technology and performed secondary research to gain a deeper knowledge of the overall drone industry. Our results indicate a rising demand for drone services as advancements in engineering have opened the door to myriad applications of drone technology. However, difficulties in acquiring and maintaining drone technology, a lack of knowledge for operating drones, and several other factors, lead us to believe that there is indeed a strong market for not only selling drone hardware, but also providing total drone service solutions.

Acknowledgements

This project could not have been possible without the contributions of everyone involved. We would like to thank the people who took time to help us out and guide us throughout the project and the people that agreed to interview with us.

We would like to thank Professor Joseph Sarkis and Professor Hansong Pu of Worcester Polytechnic Institute and Professor Shen Yunhong from Hangzhou Dianzi University for their guidance on this project.

Secondly, we would also like to thank the students from Hangzhou Dianzi University, Noora (程诺), Aletta (叶雨琪), Iris (张欣羽), Lisa (李彩红), Etta (余嘉懿), Meryl (林诗倩), and 马关泽 who worked alongside us to help interview and gather data in China.

Finally, we owe a thank you to our Sponsor RobSense for providing a wonderful and meaningful project experience, without their guidance we would not be able to get this far through our project with all the different roadblocks that presented themselves. We are especially grateful for their continued communications on the project and always providing us with the best information for us to continue working.

Executive Summary

Although drones are becoming common in commercial applications, the question of whether companies will be able to access such technology becomes more prevalent. This is due in part to the high cost of producing such equipment, as well as maintaining and upgrading said equipment. This is why the DaaS model is starting to surface and become a profitable model for both the provider and consumer alike.

Our sponsor, RobSense, is a company based in Hangzhou, China. They specialize in drone swarm technology, and they are currently implementing a DaaS business model to sell their equipment. Seeking to expand their company, they are curious about the effectiveness of such a business model both in the U.S. and Chinese markets.

Methodology

In order to help our sponsor learn about the viability of the DaaS model in the US market, The WPI research team conducted multiple business planning exercises including a Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis that included a focus on Political, Economic, Sociological, Technological, Legal and Environmental (PESTLE) factors, whenever relevant. These factors are not only relevant to the technical aspect of using drones to fulfill a physical requirement such as inspecting structures or performing surveillance, but they are also relevant to the economics of using drone technology to reduce costs and increase revenue.

To collect the data that would inform our analyses, we conducted interviews with companies in different industries that are related to the use or production of drone technology. We utilized these interviews to gain information about these organizations' opinions on DaaS

and the different factors relating to the decision to purchase DaaS versus the one-time buyout solution. Secondary source research was our ancillary method of gathering data and information about DaaS and the use of drones in the U.S. We focused on gathering information relating to the PESTLE factors, paying particular attention to regulations, market trends, and public opinions on drones.

Results

After completing multiple types of research, we were able to collect a substantial amount of information that guided us throughout the rest of our analyses for the project. From our primary research method, conducting interviews, we gathered ideas and quotes from notable companies associated with UAV technology within the US market. And from our secondary method, researching and analyzing secondary sources, we were able to learn a lot about economic trends in the US, and regulations and legislation relating to the use of drone technology.

While conducting our interviews, certain subjects were frequently brought up and these stuck out to us as important factors to keep in mind when analyzing our data. We then started on the analysis of the project which included coding the data gathered from the interviews.

We broke the interview data down into individual quotes and short passages to better analyze the ideas that came up. We created different code categories for certain ideas we had to group up the data we needed. After going over the results from our research methods, we had to identify how these themes applied to RobSense. To accomplish this, we used a SWOT analysis to gain a deeper understanding of how RobSense stands as a UAV company compared to its competitors.

Conclusion

Our final recommendation for RobSense is that within the United States, marketing drone technology using an as-a-service business model is profitable. This is due in part to the expensive nature of drones, the speed at which drones can be deployed and utilized, the advantages of being able to record data as well as to create digital twin assets such as point cloud maps or meshes, and finally, the ability to remove humans from potentially dangerous environments. Thus, it is viable for RobSense to enter the United States drone market as a total solution DaaS provider, as the benefits brought by such a business model have the potential to create immense value. We also believe that partnering with already established drone companies within the U.S. will be the best choice for RobSense's total solution model.

The final aspect of our recommendation to RobSense, is to place a high importance on attempting to obtain an FAA part 107 beyond visual line of sight (BVLOS) waiver. Although not necessarily critical to RobSense's success, obtaining a BLVOS waiver from the FAA will be very important for RobSense's ability to conduct sophisticated autonomous flights outside of the range of visual line of sight. Learning and looking into all the different regulations the FAA requires will be crucial to their expansion into the U.S.

Authorship

Giovanni Giacalone, Bright Lin, Jack Robertson, and Bryon Tom all contributed to this project. Though not everyone may have written the same amount for this report or contacted the same amount of companies, the effort put in by everyone was of significant magnitude.

During the first term of this project, all four members outlined the structure of this project and conducted a literature review. As part of the requirements for ID 2050, all members contributed to a literature review, creating a team annotated bibliography. All members also contributed to a final project proposal, writing different parts of the paper.

During the second term of the project, all members started by contacting different companies. Jack arranged the interviews with DroneUp and Optelos, Bright arranged the interviews with Cuyahoga Community College and New Mexico State University, and Bryon arranged the interview with Worcester Polytechnic Institute. The team reached out and arranged an interview with RobSense, their sponsor. All members of the team contributed to running at least 2 interviews each. After the project, a SWOT analysis was begun by Giovanni and Jack, and was later completed by the team when writing the final research report. The paper was a group contribution, with Bryon writing the introduction and conclusion and Bright writing the methods. The results section was the longest, and was written by all four members of the team.

All members of the team fulfilled their group roles admirably. As team leader, Bright was essential for maintaining communications with our Hangzhou University counterparts, as his fluency with Chinese facilitated the exchange of information. As systems manager, Giovanni helped to manage meetings and documents, facilitating group meetings as well. Jack completed his role as team manager by facilitating outings between the various WPI groups. Bryon fulfilled

his role as sponsor relations by emailing their sponsor as RobSense to arrange meetings and ask questions.

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1. Introduction

In 1496, Leonardo Da Vinci attempted to hover a rotor mechanism intended to give humans access to the sky. This ambitious attempt at early flight was not successful, however. In fact, it would be over 400 years later until the first successful human flight in 1903. Orville Wright was the first human to successfully take to the skies in a powered flight that lasted just 12 seconds and covered 120 feet. Humans had been attempting to fly for hundreds of years leading up to the first successful flight, yet when the Wright brothers constructed their modest propellor driven bi-plane, they could never have imagined the implications their invention would have on today's modern society. In the early 1900's the most common ways to travel were by foot, horse and buggy, train, or ship (Aero Corner Editorial Team, 2020). Early automobiles were still being developed and were much too expensive for many people to own yet, and mail could take weeks or even months to travel cross country. In 1918 however, the first airmail transport was commissioned to decrease delivery times for mail and perishable goods. In the years since the advent of the airplane, the ability to fly has revolutionized the way humans travel, deliver goods, fight wars, create maps, and many more things.

It was not always preferable for humans to pilot these planes, however. Especially in war times, it was desirable to fly a plane into enemy territory without having a human pilot in direct control of the vehicle. Thus, the Unmanned Aerial Vehicle (UAV) was invented. This new innovation within the flight movement opened doors to many new applications for UAVs. Quadcopter drones were developed and began being commercially sold in the early 2010s as a method of capturing footage from the sky. Early cameras used onboard these drones were GoPros and other cheap consumer action-cameras. As brushless gimbals were developed,

footage acquired by these drones became better in quality and commercial quadcopter (four propellor) drones gathered more public interest. As commercial drone technology became more sophisticated, their applications grew. Today, millions of drones take to the skies, employed in dozens of industries worldwide. Just like the airplane, drones have revolutionized many aspects of daily life and the applications are still expanding.

Developing drone technology is expensive and time consuming, leaving smaller companies, which do not have the necessary resources to build their own drones, restricted in their choices to adopt drone technology. Some companies buy their drones from other companies that specialize in drone production. This leaves the buyer with more freedom of use, but little support for how to best use them to generate value for their business. Little research, however, has currently been done on the feasibility of a drone rental service that not only includes drone hardware, but also supporting software for the control of the drones, software for the analysis of collected data, and training for pilots hired by the buyer. RobSense, the project sponsor, is a leading company in artificial intelligence (AI) research and development for auto-pilot systems and applications. It is believed by Robsense that the service business model is in fact profitable, but they lack some information concerning what specifically is desired by buyers within the market as well as what areas of the UAV industry to focus on in order to develop as strong a company as possible.

In this paper, we will provide a recommendation for RobSense, on the feasibility of expanding into U.S. and Chinese markets with a “Drones-as-a-Service” (DaaS) business model. This business model will primarily focus on providing drones and other related services to companies seeking to adopt drone technology. We will base our recommendation on factors including, but not limited to, current demand for drone technology, the desired price ranges from

companies and organizations that we interview, and laws and regulations regarding drone use in the U.S. and China.

2. Background

This section will outline some of the current technology available and its uses in the market as of the present. This section will also relate these concepts to the focus of the project -- offering a business model suggestion based on existing drone ecosystems.

2.1 UAV History and Technology

Unmanned vehicles have been used for decades to carry out tasks that would not be ideal for humans to do. War tends to accelerate the advancement of technology, and this is no exception for unmanned vehicles. Drones were first introduced through warfare, and even used as targets for military practice. Early examples of drone technology would be fireships, which were used in maritime warfare (Merkert, 2020). Fireships are unmanned ships filled with explosives that could be pushed or directed to sail into enemy territories to cause destruction without putting the senders of the attack in direct danger. Even as far back as World War 2, unmanned planes have been used to disrupt airspace over cities as well as drop ordnance over enemy-controlled territory. Fireships were not technologically advanced, however, and the unmanned planes used in World War 2 did not look or perform anything like the drones of today's time. This is because the first drones did not have any autonomy or remote control.

2.2 Commercial Usage of UAVs

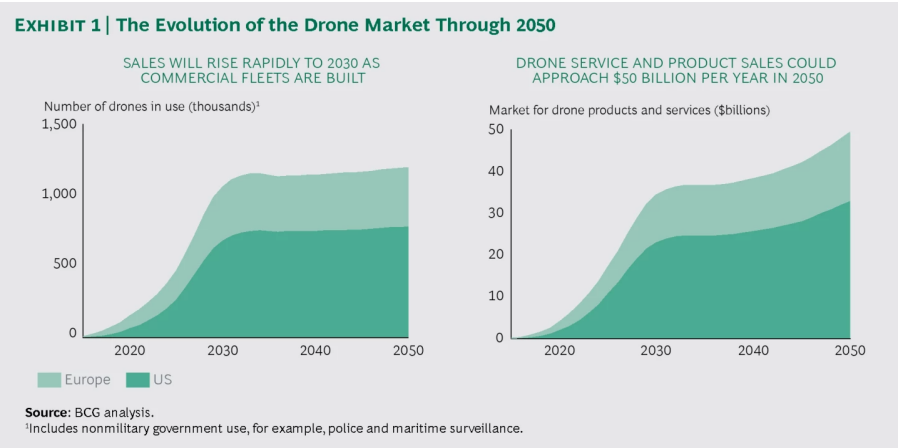
Drones in today's time are remotely piloted or even fully autonomous. Now, all drones have at least a certain level of autonomous capability. Even if a pilot is in full remote control of a drone, the drone's flight computer, also known as the flight controller, is still receiving a stream of data from various onboard sensors including but not limited to gyroscopes, accelerometers, GPS modules, barometers, and cameras. With these tools, their integration for civilian use was facilitated. These sensors enable the drone to perform the computation of altitude, its location in space, and its location in relation to obstacles (Clarke, 2014), as well as control of the motors to spin at the exact speeds required to maintain the current altitude. This is a level of self-micromanagement that could not realistically be done by a remote pilot and is therefore delegated to the onboard systems. For this reason, we will consider drones to be unmanned aerial vehicles that are capable of observing their environment by reading sensor data and are either remotely piloted or fully autonomous but retain at least a small amount of autonomous decision-making capabilities. With technology evolving throughout the years, drones gained new capabilities, resulting in their increased use in military operations and commercial uses. The miniaturization of electronic components, and the increased computing power of processing units, among other advancements, such as camera developments, have made small drones more affordable and attractive to consumers (Giones & Brem, 2017). Quadcopter drones greatly benefited from the miniaturization of high-definition video cameras which have become a central component for these. Through time, we have observed that technological progress and drones for military use have worked in parallel as a response to the demand for drones with enhanced capabilities. In the civilian market, we are witnessing an ongoing search for applications for existing drone technology — a technology-push (Giones & Brem, 2017). A technology push

refers to when a producer has to seek a product advantage for the consumer, that the consumer does not see themselves.

2.3 The Modern UAV Industry

As drone capabilities increase over time, so do their potential applications. In the years since World War II, electronics and communications technology has progressed rapidly and allowed for drones to expand out from military use and find demand within various commercial industries. As this trend continues it is expected that drones will play a very significant role in the future of how humans do business. In fact, one of the world's largest and most well respected global management consulting firms, Boston Consulting Group (BCG), estimates that by the year 2050, the industrial drone fleet in Europe and the US will comprise more than 1 million units and generate $50B per year in product and service revenues (see Figure 1).

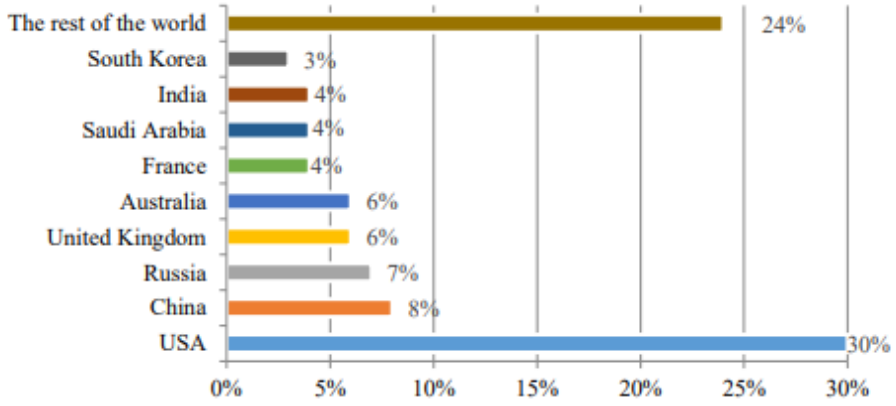
Figure 1: Estimated Growth of the Done Market



Note: BCG estimates the growth of the Industrial Drone Fleet in Europe and the US by 2050 (Amoukteh, 2021)

The global drone market is also estimated to triple in value in the next five years (Kapustina, 2021), with USA and China leading the effort to adopt drone technology. (see Figure 2)

Figure 2: Drone Sales Around the World



Note: Geographic structure of world drone sales, 2019 (Buchholz, 2019)

Many new commercial applications ranging from agriculture, surveying, public safety, and delivery, to construction, research, and defense are growing, the uses of the emerging technology are seemingly endless. Although a large majority of drones remain military in use, in recent years the flexibility and versatility of drones have led to the fast adoption of the technology by non-military industries as well. Camera attachments allow photographers and videographers a new way to capture the world, the entertainment industry not only uses drones to film sports events but also to construct light shows with swarms of drones all flying in synchronicity to music. Even more impactful are the applications of this technology in addressing global health issues. With the recent rise of the COVID-19 crisis, drones have served as delivery platforms for medicine and other essential goods. In recent years, flooding in Fiji has left large amounts of standing water for long periods of time (Wood, 2021). This water has served as a breeding ground for large populations of disease-carrying mosquitoes. While

insecticides have done little to solve this deadly issue, drone technology has given researchers the opportunity to release mosquitoes treated with a bacteria called Bacillus thuringiensis which reduces their virus-transmitting ability. This has been shown to have a great effect on the control of the mosquito populations. Drones are also helping to solve global warming and pollution issues. Specifically, in Panama, drones have been used to seed large areas of land with mangrove trees for short periods of time. Mangrove trees were chosen because they store five times the amount of carbon compared to other tropical trees. The use of drone technology here has helped to speed up the process of saving the earth while also cutting costs, further increasing the efficacy of anti-global-warming efforts. Currently, drone technology is the most widely adopted within the photography, media, agriculture, and energy industries. Within these industries, drones create immense value since the technology does not require a human pilot. This significantly lowers the cost of operation because having a human payload is large, heavy, and expensive. With no need for human life-support systems such as pressurization control or air supply, drones also have a very low energy consumption (Otto et al., 2018). In a research paper about drone sensing for forest research, it's speculated that as more accurate sensors are produced and more sophisticated software is developed, many different applications of drones will become far more appealing to consumers (Tang & Shao, 2015).

Aside from logistical issues related to the maintenance and upkeep of a drone fleet, it may be that the increasing price of drone technology is the primary obstacle for widespread commercial drone adoption (RobSense representative, 2022). Many large companies have already invested millions into drones and have begun to use them in commercial applications. For example, DHL uses drones to deliver packages, and Yamaha uses their Fazer (see Figure 3)

and R-MAX drones for the aerial spraying of crops, but many smaller companies may be either unable or unwilling to currently invest in a fleet of drones for their own use.

Figure 3: Yamaha Fazer Drone

Note: Equipped with Crop Spraying Technology for Agricultural Applications (Image from a2zvehicle.com)

2.2 Project Background

Our sponsor, RobSense, is a company based in Hangzhou, China. They specialize in drone swarm technology, and they are currently implementing a DaaS business model to sell their equipment. Seeking to expand their company, they are curious about the effectiveness of such a business model.

This brings us to the primary purpose of our project: to judge whether selling unmanned-aerial-vehicle (UAV) technology using an as-a-service business model is profitable.

An as-a-service business entails leasing out drone equipment as well as extra support, potentially in the form of pilots or staff. The company using such a business model will oftentimes provide hardware and software updates, keeping the leased equipment relevant. However, these benefits often mean that companies buying into such a service will often pay more money over time than a company that fully purchased its own equipment. Thus, it is our goal to research data concerning the drone industry in order to see whether these benefits will outweigh the downsides.

This project aims to analyze the drone market within China and the United States and evaluate the feasibility of DaaS to be a profitable business model in the security application space. In order to achieve this, we have outlined three main objectives to work towards throughout the project.

Firstly, we will research the demand for drone technology within the market of private security. We desire to gain insight as to what consumer needs are addressed with the usage of drone technology, as RobSense needs to develop a service that appeals to multiple companies.

Secondly, we will identify drone technology customer demographics within China and the U.S., focusing on small to medium-sized companies, as larger companies possess the funds required to develop or purchase their own drone technology and are not the target customers for the DaaS model RobSense is trying to introduce. However, if the DaaS model proves to generate significant value for its customers, large corporations may end up being potential consumers as DaaS could provide additional functionality that was previously unavailable if they had bought their own drones.

Finally, after identifying the potential customers of DaaS, we will interview them in order to determine the factors that contribute to their choice to purchase drone services, as well as what kinds of services they would be interested in paying for. While these factors could simply be desired hardware and software features, factors could also include additional services provided by the as-a-service business model such as data analysis tools, support for training new pilots, and more. We will also conduct research on these companies in order to understand what demographics these companies will fit in. This will help us to categorize the information obtained, allowing us a more accurate analysis at the close of the project. Knowing the customers' needs as well as their demographics will enable RobSense to gain a better perspective on both the demand for drone technology and the potential for a DaaS company to be profitable and grow in today's market.

We will also need to analyze the recent economic growth of drone technology. While this consumer information will allow us to create a more appealing business model, it is vital that we also make ourselves aware of how relevant drones are within the economy in order to know whether a business model based around them would be profitable. As we continue on through the methods we will be talking more about our methods of interviews, who we will interview, our interview structure, the further analysis of prior work, and lastly the limitations we will encounter.

Our primary research method was interviewing companies within industries that could make use of drones. These interviews will be conducted both in the U.S. and China. The industries we mainly settled on included other drone providers, security companies, and universities. The interview questions were geared towards attempting to identify which industries would have the greatest demand for UAV technology, as well as what factors contributed to an

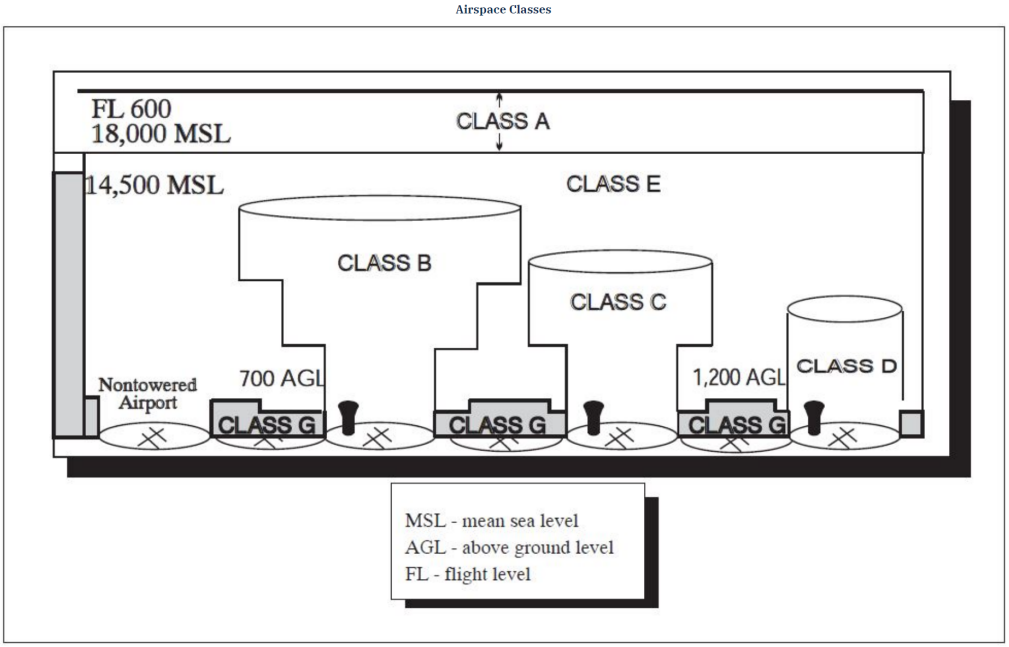
individual organization's rationale for purchasing such technology. Understanding the multitude of use cases for drones would potentially allow RobSense to better develop services for these companies while researching what influences the decision to purchase drones would allow us to better judge RobSense's current practices.

The secondary research method we chose was the review of secondary sources, including but not limited to economic reports, drone laws and regulations, and news articles. It was vital for us to understand the extent that drone flight regulations limited the commercial usage of drone technology.

2.3 Literature Review

Regulations that outline the use of small UAVs are detailed in the Federal Aviation Administration's (FAA)'s part 107 guidelines. These regulations apply to drones that weigh less than 55 pounds, and it is with this class of drones that most civil and commercial applications of drones are conducted. Part 107 requires that pilots and drones are certified by the FAA and that the drone is registered with the FAA. For use outside of class G airspace, drone pilots are not required to receive authorization from air traffic control (ATC). Class G airspace is loosely defined as "that portion of airspace that has not been designated as Class A, Class B, Class C, Class D, or Class E airspace" (Federal Aviation Administration, 2020), and this uncontrolled airspace can be most easily thought of a airspace outside of airports and below 1,200 feet off of the ground.

Figure 4: Classes of Airspace

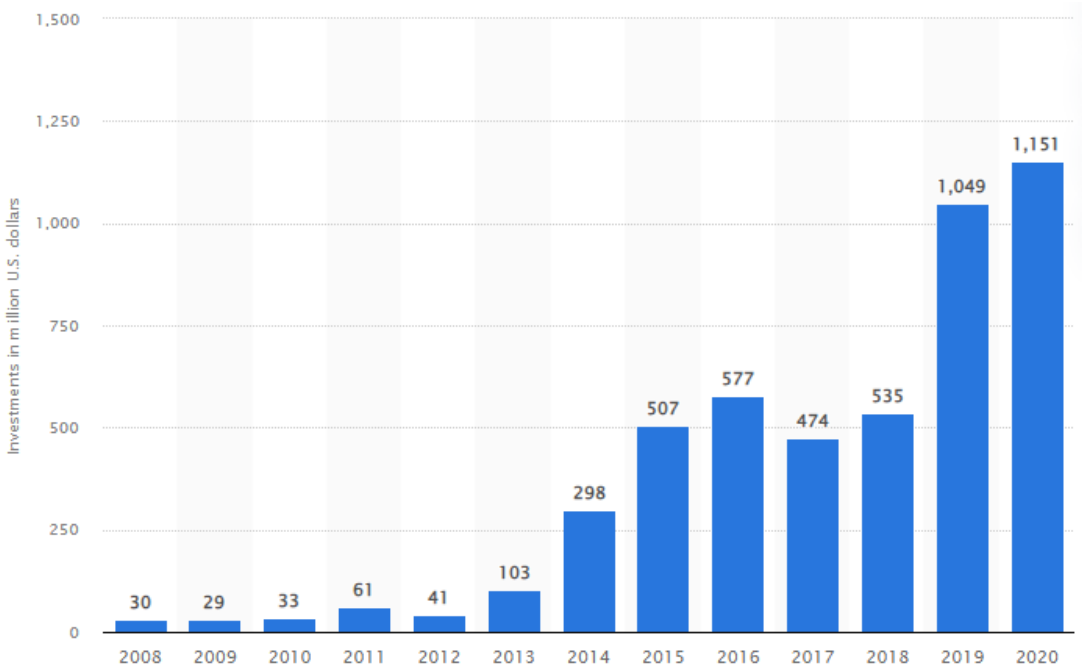


Note: A diagram showing different airspace categories (Federal Aviation Administration, n.d.)

Within Class G airspace, part 107 includes guidelines restricting the flight of drones. Some of these exclusions include bans on flying at night, flying BVLOS, flying over people, and limitations on drone speed and carrying capacity. Companies or individuals may request waivers from the FAA that grant them exemptions from the restrictions outlined in Part 107, but the operation of the drone under those exemptions must demonstrate "a level of safety at least equivalent to the restriction from which you want the waiver" (Federal Aviation Administration, 2020). The FAA offers ease of access to its drone-related services through its FAA DroneZone platform, which it cites as an all-in-one location for drone needs ranging from filing registration or requesting waivers.

Looking at the state of the drone market, market analyses and academic articles suggest stable investment and an optimistic future with a high rate of growth. A report on the global commercial drone market estimated that "In 2020, 1.1 billion U.S. dollars were invested in drone companies," and projected that the international drone market would be worth $44.1 billion USD by 2024 (M. Placek, 2022).

Figure 5: Graph of Investments in Drones



Note: Shows the annual investment in drone companies from 2008-2020 (DRONEII, 2021)

This upwards trend is corroborated by other articles and journals, with a quarterly update on the Aircraft Engine & Parts Manufacturing industry mentioning that "the [drones] industry is expected to grow rapidly. Global delivery drone market is expected to grow from $1.26 billion in 2021 to $1.47 in 2022 at a compound annual growth rate of 17.3%" (First Research, 2022). With such a high projected annual growth rate, in a single area of the drone sector, no less, it is

unsurprising that economists anticipate explosive performance from the drone market in the future.

2.4 Research in Perspective

When looking at existing articles documenting the state of the drone space, many of them talk about technological aspects and reference hopes for the future. Articles from academic journals, such as the National Library of Medicine, and posts from online blog posts, such as Pinnacle Digest, both share perspectives on the current uses of drones. Similarly, from both sources, it is common to hear about the future of drone technology and its ability to bring new capabilities to commercialization as the technology advances, but given that our project focuses on catering a recommendation to our sponsor based on business models, these publications are best used as reference points for the public and professional perspective on the use of drones and to get an understanding of how the technology seems to be advancing. From such technological discussions, we sought to include in our recommendation some relevant technologies that would enhance a company's competitiveness in the industry, such as BVLOS flight. For economic insights, we turned to IBISWorld and Statista. These resources are databases of industry information and reports that were invaluable in offering an insider perspective on the business side of the drone space. Notably, our project sought to inform our sponsor with recommendations based on the DaaS business model, and such specific information, from what we could decipher, was not readily available with any sort of depth. To link our market analysis with a focus on the as-a-service model, we compared the drone space to other areas in which the as-a-service model has seen success and widespread adoption. One such area is the software industry, where

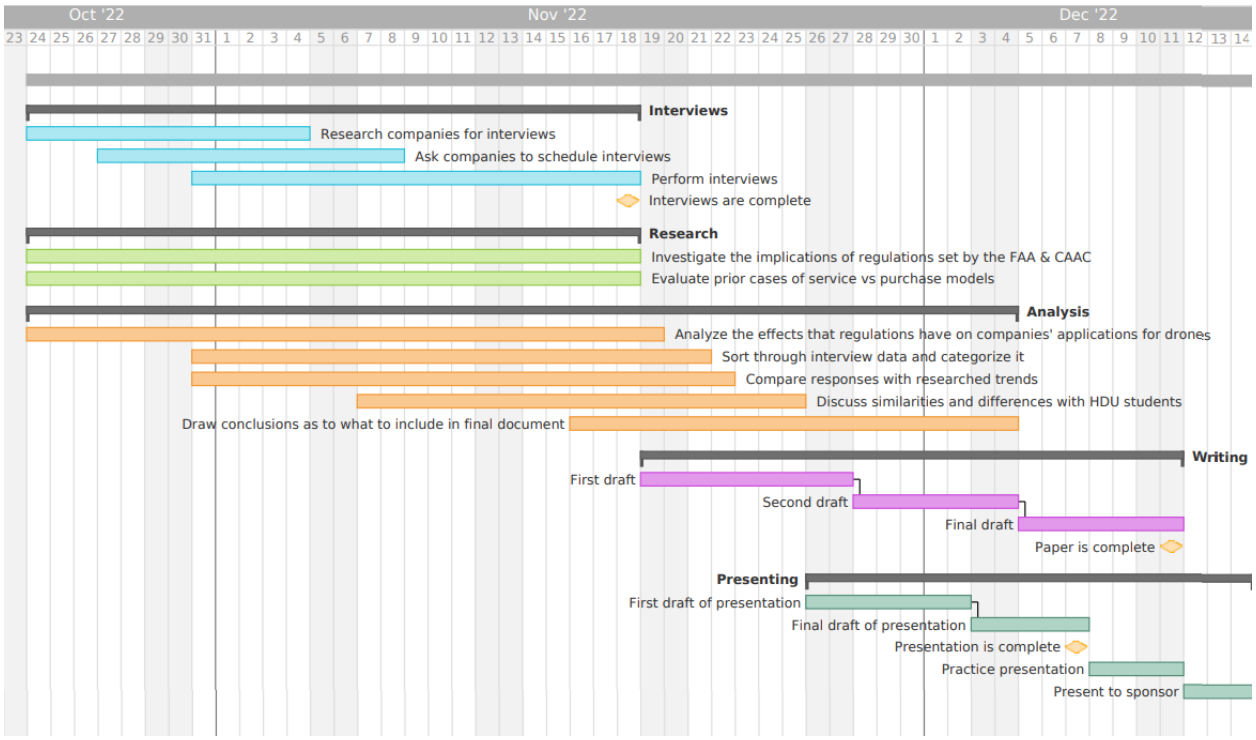
Software-as-a-Service (SaaS) has seen rapid development and implementation across a variety of companies, with a particular example being Adobe (Vested Finance, 2022). Seeing the aspects that make SaaS competitive in its market space provides lessons and a basis from which we can cater our suggestions on DaaS for RobSense in the drone industry.

2.5 Limitations

For this project, notable roadblocks include the difficulty of finding interviewees, the accuracy of the information gathered, and the relevance of the research papers we find. First, the most important problem that we have for our project would be that there is no guarantee that we will secure enough interviews in order to collect a sufficient amount of data. The primary method of gathering data for us will be interviewing and talking to companies, schools, or other organizations that require security. However, getting in contact with and securing an interview with these organizations we have no association with will be difficult. For example, companies may not allocate the time or have enough patience to talk to our team since we are only college students and they have no obligation to work with us. Ultimately, this could result in them writing off our request as unimportant or insignificant. A flaw in the design of our methods is the accuracy of the information we gather from either interviews or research papers. If we conduct interviews with RobSense's competitors, we will have to account for the possibility that some of the companies interviewed will answer untruthfully or provide us with misleading information.

We have provided a week-by-week Gantt chart to show our tasks throughout the 7 weeks of the research project.

Figure 6: Project Workflow Gantt Chart



Note: Gantt Chart of task breakdown while completing the project.

3. Methods

In this section, we detail the process we used to gather the information necessary to complete the project. We break down the two overarching strategies for data collection and outline some of our thoughts related to our selected methods.

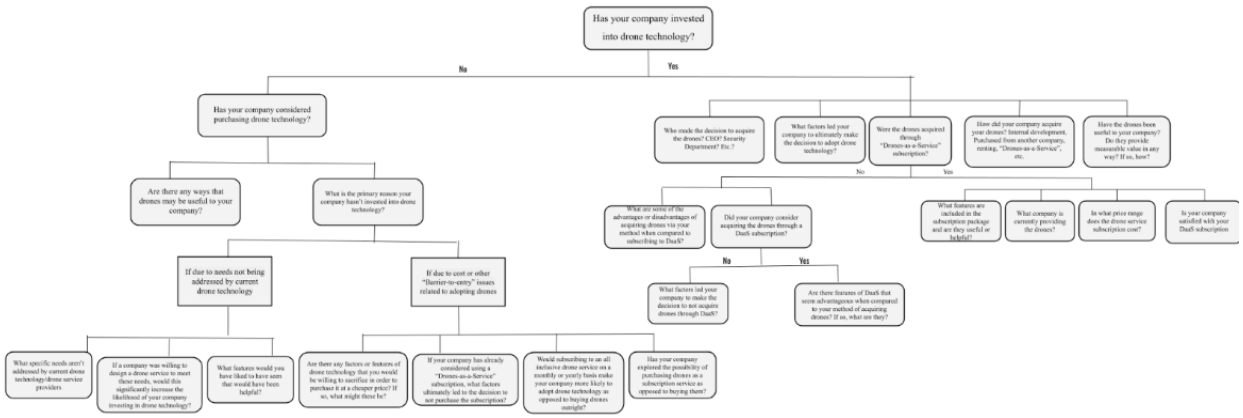
3.1 Interviews

Interviewing and speaking with a wide range of businesses and organizations with connections to drone technology served as the primary technique for obtaining data to support

our ultimate goal. The Hangzhou Dianzi University (HDU) team will interview organizations in China, whilst our Worcester Polytechnic Institute (WPI) team will interview organizations in the United States. We investigated and examined a wide range of interview prospects before deciding to contact a select few that were particularly pertinent to RobSense. These organizations included universities, drone suppliers, energy and utility providers, security companies, and much more.

These interviews will be semi-structured. This is to ensure that we are able to obtain information vital to our project from every interview. However, we understood that different companies would be inclined to discuss different aspects of the industry, with many companies potentially introducing topics that we would not be able to foresee. Therefore, by implementing the interviews as only semi-structured, we hoped to glean as much information as possible from the interviews.

Figure 7: Interview Question Flowchart



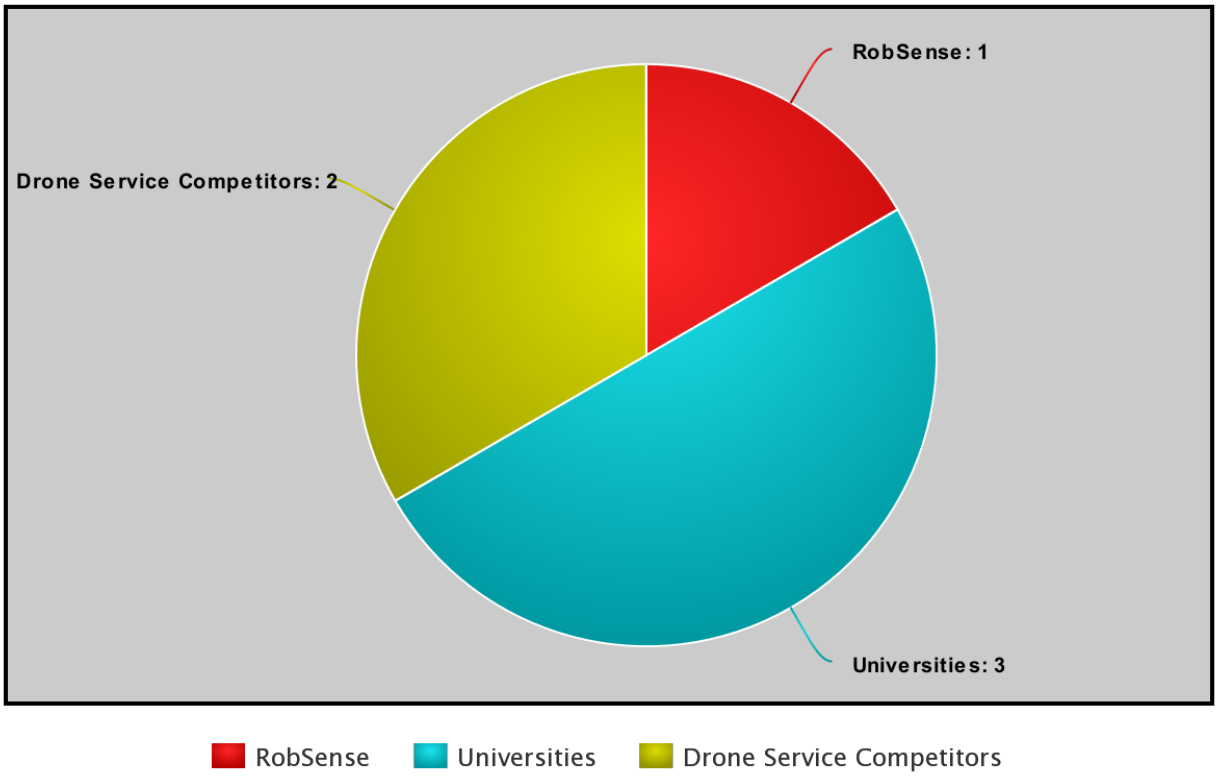
Note: Initial plan for interviews, would eventually be revised

3.1.1 Identifying Interviewees

The several universities spread around the United States were the first group we contacted. There were several factors when deciding which universities we wanted to reach out to, but the key consideration when choosing which institutions to contact was whether or not they had previously deployed drones for campus security. We concentrated a lot on the institutions that had drones on their campuses or are still employing them, and they were generally receptive and supportive of meeting with us. In the end, compared to the other groups we contacted, universities were also the most likely to reply and accept to be interviewed.

As time progressed, we started to reach out to other drone companies that could be competitors or partners to RobSense. Interviews with these companies were critical because they provided valuable information about DaaS and the various regulations governing drones in the United States. The organizations mentioned in table 1 were the only ones who responded and with whom we were able to meet **(**See Appendix A for the full list of companies that we contacted). Below we will show the total amount of interviews we have done and their types of industries (see Figure 1).

Figure 8 : Final Interviewee Industries



Note: Pie chart of the type of interviews conducted

The HDU team has looked at a variety of organizations that were similar to ours. Those interviews mostly consisted of many different companies and universities that appear to be very interested in drone security capabilities. We decided to keep our interview targets consistent across both teams in order to achieve the best results when comparing the US and Chinese markets. Despite having only a few interviews, we obtained enough data and knowledge for our team to make a helpful recommendation to RobSense about expanding into the United States. To address the many different types of organizations being interviewed, we catered our questions to each of them individually. Learning and researching about the organization beforehand was crucial to creating specific questions that would be relevant to the interview at hand.

3.1.2 Identified Interview Subjects

DroneUp is a company centered around supplying drones to be used by companies throughout the United States. Their business model is centered around creating a network that is capable of supplying drone services nationwide. To achieve this, they purchase and modify drone equipment, partnering with pilots throughout the country, and enabling them to offer their services in multiple states.

Optelos primarily provides solutions for the management and interpretation of visual data. As a representative stated during an interview, "The biggest problem - after ‘I don't have a drone pilot’ - is ‘how do I store this data?’”(M. Bauman, personal communication, November 11, 2022). As autonomous drones grow increasingly common, the institutions utilizing these UAVs require ways to analyze the data obtained. Optelos offers an easy-to-use, organized data management platform. With regards to the drone industry as a whole, they offer customers software that facilitates the interpretation of data obtained from autonomous drones.

New Mexico State University (NMSU) and Cuyahoga Community College (CCC) are both educational facilities that have used UAV technology in the past. However, their experience with drones has differed in the way they came to acquire the technology. MNSU received the drones as a donation from a student organization that had purchased drone equipment, only to discover that such equipment couldn’t be operated on university grounds. On the flip side, CCC made the decision to purpose drone equipment, believing it to be an asset to education and security. These differences will make themselves apparent, as each institution had a very different outlook on drone technology as a result of their different experiences implementing

UAV technology. See Table 1 for more information about the different organizations we spoke with.

Table 1: Basic Information of Interviewed Organizations

Company / Organization	Details
RobSense	RobSense is our sponsor company and is in the business of providing drone solutions as a service.
Optelos	Optelos is a visual inspection data management company that specializes in scalable data management, automated visual data analytics, and AI.
DroneUp	DroneUp is a flight services provider that partners with independent drone pilots to provide drone services to other companies in industries such as Commercial Real Estate, Construction, Insurance, Maritime, Infrastructure & Utilities, and Security.
New Mexico State University	New Mexico State University (NMSU), located in Las Cruces, New Mexico, used Drones in its campus police efforts over the span of several years to address a variety of problems that could be solved more easily with the help of drone technology.
Worcester Polytechnic Institute	Worcester Polytechnic Institute (WPI), located in Worcester, Massachusetts, has not yet used drone technology for campus police or other uses.
Cuyahoga Community College	Cuyahoga Community College (CCC) is a university located in Cuyahoga County, Ohio. They have programs wherein they implant drone technology in an educational way. The representative we spoke to was also a member of the local police force, and had been pushing for

	further implementation of UAV technology in multiple areas.

3.1.2 Interview with RobSense

The most important interview that we conducted was with our sponsor RobSense. We needed to learn everything about them to construct the best suggestion we would provide for their expansion into the U.S. This is why we decided to do a SWOT analysis of RobSense, which is to identify and analyze their strengths, weaknesses, opportunities, and threats. This way we would have a solid understanding of RobSense's internal strengths and weaknesses and external opportunities and threats that shape current and future operations and help develop their strategic goals. The questions we made for RobSense were asking about the company itself and what they were capable of doing. We asked specifically about topics that would be strengths or weaknesses for RobSense's expansion into the U.S.

3.1.3 Interview with Universities

Universities emerged as strong candidates during the search for potential interviewees. Universities were a potential customer group for RobSense because of their potential need for campus security and safety. Drones can be seen to be capable of providing very reliable security-based applications due to their numerous features such as live video feeds and full aerial views. This is why we focused our efforts on contacting universities that have explicitly stated their past or current deployment of drones on their campuses, so that we can learn more about the strengths and weaknesses of drones in campus security.

Worcester Polytechnic Institute, New Mexico State University, and Cuyahoga Community College were the three universities we were able to speak with. Because Worcester Polytechnic Institute has never used drones for campus security, our interview questions focused on their thoughts on drones and their applications. We also wanted to learn more about the DaaS business model and how they felt about the model's pricing.

The next interview we conducted was with New Mexico State University (see Appendix B). This university had previously deployed a drone for campus security purposes, but had to discontinue the program due to a variety of factors. The questions we devised for them primarily focused on inquiring about their applications of drones when they were deployed (Question 1), their monetary expenditures on the drones (Question 4), and the perceived usefulness of the equipment (Question 7).

Cuyahoga Community College was the last institution we spoke with (see Appendix C); it has a large drone academy and has used drones for security and safety for many years. In comparison to the previous institute mentioned, this college had approximately fifteen drones at their disposal. The drone academy offers a variety of drone classes to public safety personnel, with the goal of having them bring the knowledge and skills back to their departments and deploy their own drones. Because the drone academy's director is also a police officer, the local police department relies on drone technology for public safety. For the purposes of learning new information, the questions we asked this institute were similar, being about the methods and costs of obtaining their drones as well as their performance during their deployment (Questions 4 & 7).

3.1.4 Interview with Drone Companies

Being directly involved in the drone industry, other drone companies will naturally provide vital insights concerning the future of UAV technology. While interviewing these companies wouldn't provide us with a direct source concerning what consumers want from a DaaS business model, we would gain valuable information concerning how the drone industry currently functions, as well as potential suggestions that Robsense could implement in order to facilitate the expansion of their company (see Appendix D).

Our interview questions were coded, with different questions intended to discuss different concepts that were all relevant to our study. The first two types of questions discuss their own experiences with marketing UAV equipment. One type addresses the financial portion of drone services, including the rough pricing for the equipment and services (Question 5), while the second type addresses the customer's involvement in buying the service (Question 2). These questions were broader, inquiring into services and options their customers have had available to them, as well as trends regarding the company demographics of said customers. These questions would help us identify which industries could potentially provide promising partnerships for RobSense. The last couple of question types delves into the logistics of running a functioning drone company. Some of these questions aimed to discuss the various expenses that come with UAV technology (Question 8), while the final set of questions was about the specific software and hardware of drone equipment (Question 4). These questions help to inform our understanding of the economic viability of the drone industry in the future, while also giving us information that could be used to make additional recommendations to RobSense concerning the direction of their company.

3.2 Secondary Research

Besides our main methods of collecting information and data, we decided to look into secondary sources discussing drones and the many regulations surrounding them. Throughout our interview with Optelos, we learned about a regulation concerning drone flight which is called Beyond Visual Line of Sight (BVLOS). This is a law where no one is allowed to fly BVLOS in U.S. airspace without obtaining a special, hard-to-get waiver from the Federal Aviation Administration (FAA). We went further in-depth into this regulation and figured out the requirements for a company to get this waiver from the FAA, this way if RobSense can get this waiver they will have an immense strategic advantage over other competitors in the U.S. market.

During the interview with the New Mexico State University, we learned about the Criminal Justice Information Security (CJIS). This is another regulation that would have to be met by RobSense if they want to partner with organizations such as campus police. This regulation deals with information integrity if drones were to be used during security and safety operations where there is recorded evidence.

3.3 Analysis

After enough research has been completed, we will launch a SWOT and PESTLE analysis of the gathered data. We will primarily be looking at RobSense's strengths and weaknesses as a company in comparison to the technological specializations and business models that are projected to be the most effective. Understanding this will give us the knowledge to judge whether or not RobSense's implementation of DaaS will be viable in the future. This will also allow us to gauge the success of RobSense's potential decision to expand into other

markets utilizing a DaaS business model, enabling us to give RobSense recommendations concerning how it should go about expanding its business.

4. Results

In this section, the information gathered by our team through our two primary means of data collection is analyzed and related back to project objectives. To achieve this, categories were outlined to sort the information and facilitate the continuity of ideas in subsequent areas of analysis.

The primary mode of collection for information relevant to the project was through interviews with universities and other, competing companies that also offer services with drones. Additional information was collected through academic journals, government guidelines, and other forms of official literature. The WPI and HDU teams worked independently to obtain interviews in their country of residence, the US and China, respectively, and the insight that each team learned was compared and contrasted with the learnings and trends considered by the other.

4.1 Interview Results

The number of interviews conducted by the team was only a small portion of the number of companies/universities that were contacted, and the success rate for scheduling an interview with a group that had been reached out to was around 6%. From among the varying perspectives on drone technology and its efficacy in deployment through an as-a-service model emerged a few major, repeating themes. Below is a chart that lists each theme and describes the significance of the theme as a code for labeling response data and how that theme might relate to the PESTLE factors that will be relevant to our SWOT analysis (see Table 2).

Table 2: Interview Coding Categories

Code	Significance
Safety	This code was used to label a quote or piece of information pertaining to public safety, safety risks or concerns, and safety benefits relating to the use of drones as opposed to the previous solution for any application of drone technology.
Value / Cost	This code was used to label a quote or piece of information as relating to the monetary advantages or disadvantages of obtaining drone technology. Purchasing DaaS solutions may cost more money in the long run but may provide more valuable information that was otherwise unattainable before using drone technology. (E.g. the creation of digital twins for inspection applications).
Technology	This code was used to label a quote or piece of information that relates to technological advancements or capabilities within the drone space.
Use Cases	This code was used to label a quote or piece of information that showcases one or more opportunities to deploy drone technology in an industry that may provide value to the company seeking the drone service.
Staffing	This code was used to label a quote or piece of information when

	pertaining to the number of employees required before and after drone technology is deployed. (E.g. An additional employee may need to be hired as a result of beginning to use drones, one less employee might be required to be present due to the drones' versatility, etc.).
Regulations	This code was used to label a quote or piece of information that gives insight into how government regulations (E.g. Federal Aviation Administration) may affect RobSense's ability to work within the United States.

4.1.1 Safety

This code relates to the sociological factor of our PESTLE analysis because safety is a significant aspect of social life and this code helps us understand the implications that drone technology could have on the well-being and security of individuals and/or communities.

One of the primary arguments for the use of drone technology is the safety it will provide in many different situations. Throughout the interviews we conducted, the ability to use drones to limit the risks to human life was frequently mentioned and seen as a major benefit when discussing the use of drone technology. This was explicitly mentioned during our talk about flare stack inspections with Optelos, Using drones instead of having to set up scaffolding would result in a quicker ROI and also have a lot of ancillary benefits as well such as safety, efficiency, and the longevity of data (M. Bauman, personal communication, November 11, 2022). The safety of

human lives is always the main priority and using drones to do inspections on a highly dangerous situation is safer and more efficient.

This safety aspect is not always an advocate for the use of drones. A prime example of this is when the WPI representative stated "You always have to make an analysis on the risk versus the rewards" (WPI representative, personal communication, November 18, 2022). This was a situation where drones could be used to inspect rooftops in the daytime and the fact that drones could malfunction was mentioned. There are hundreds of students walking around during the day, with these drones posing significant risks towards students. The safety of the students should always be prioritized, thus the risk should always be looked at versus the rewards of using this new technology. Safety can not only be seen as a good thing when using drones for dangerous situations but could also be seen as a negative when there are potential malfunctions in the technology.

4.1.2 Value / Cost

This code most closely relates to the Economic factor of our PESTLE analysis because value and cost are ideas that are central to the understanding of economics. In the example of purchasing DaaS, the marginal benefit may be significantly higher than the additional marginal cost of obtaining these services, so the decision to purchase DaaS would be economically wise. The reverse statement could be true as well.

This theme saw more division than others and highlights itself as a particular area of interest for those who are interested in UAVs. Cost is also a major consideration for the creation of a DaaS service model as it is one of the most direct comparisons that can be made to the traditional purchasing model. During the many different interviews we conducted, the cost of the

DaaS model was always discussed. The DaaS model was not only created for the different services it could provide but also for the more stable cost and equipment updates.

This was particularly seen at CCC where they had a major problem with having to find funding for the newest technology of drones. They had done a one-time purchase of their drones for around 3,000 to 20,000, but after a few years the equipment became outdated and they needed to buy the newest equipment because the older ones did not support newer features. This is why the representative of CCC said that "It is easier to have a good price point each year so they don't have to purchase new technology every couple of years" (Cuyahoga Community College Representative, personal communication, November 14, 2022). He mentioned that they would need to add another 18 to 19 thousand into the budget to get new equipment and how it would be really hard to find funding for such a large amount of money. Instead, if there was a DaaS model that would only cost around 2 to 3 thousand a year for the drones and all the services, finding funding would be much more manageable.

A similar situation can be seen at NMSU where their drone program was discontinued due to the high cost of maintaining newer equipment and training of personnel. When looking at restarting the drone program they saw that "The estimated cost of updated equipment and training for 2020 was $7,000, and $3-5,000 for annual budget" (New Mexico State University Representative, personal communication, November 9, 2022). They had to factor in many different costs to restart the program but the most costly one would be maintaining the equipment. This is why the DaaS model could potentially be a really good fix to these problems, since the providers would have to keep their equipment up to date constantly every year at no extra cost to the consumers.

Despite this comparison, it is difficult to directly compare the cost saved by replacing traditional industry practices with drones. Referring back to the smokestack inspections discussed in the Optelos interview we can estimate that the usage of UAVs can save over $200,000. However, a drone viewing a large outdoor event for security purposes accomplishes a task that typically couldn't be fulfilled in the past; therefore making it difficult to quantify the money saved by the company investing in UAVs. Because of this, we instead concluded that drones are best purchased by industries with use cases that are better or only solved by drones.

4.1.3 Technology

This code directly relates to the Technological PESTLE factor because this factor has to do with all things related to technology. The aspects of technology in the drone space that have the greatest impact on the recommendation to Robsense were in data analysis and autonomous flight, with AI productivity offering benefits to productivity and efficiency in both areas.

In our interview with Mark Bauman, the Vice President of Marketing for Optelos, he surmised that two of the greatest problems facing those who wish to use drones are finding a pilot and storing the data (personal communication, November 11, 2022). Drone flight services command a significant portion of the utility provided by a DaaS solution, but the recent trend among service providers is to offer analysis and modeling using data collected during flight. Investment into data storage and modeling services by potential competitors to Robsense, Optelos, and DroneUp, corroborates that analysis is in demand. AI facilitates the delivery of this service by streamlining data review for users, with an example having select images from a database of thousands being flagged based on parameters set by operators. This prevents the

need for a person to look through every image individually and reduces the time necessary to evaluate the dataset.

With regards to flying autonomously, this capability is currently limited by the existing regulations governing that drones must be piloted within line of sight. A strength of this approach is the removal of the human element as it eliminates the human error associated with piloting drones. This strength is reinforced when introducing a sufficient AI model for obstacle detection and avoidance, as it creates new possibilities for creative deployment of automated drone solutions. Mark Bauman sees the future of drone services as one where drones can fly and complete tasks within a designated space using automated obstacle detection and avoidance technology. This is a forward looking perspective, though, and such automation is not widely available or effective in its current state.

4.1.4 Use Cases

This code can relate to the Environmental PESTLE factor because it can lead to the discovery of use cases for drone technology that is more energy efficient or leads to fewer emissions when compared to previous solutions. It can also relate to PESTLE factors such as Economic and Sociological.

As identifying which industries had the most pressing use cases for drones was one of our project goals, it was only natural for drone use cases to be a recurring theme throughout our interviews. The most prominent use case that we saw was utilizing UAVs to perform infrastructure inspections. RobSense has worked with power line companies in the past, creating a precedent that we would see often. Optelos discussed how drones were useful in oil and gas flare stack inspections, as drones would cost less than $10,000 to complete the task in roughly an

hour, while traditional means cost around $250,000, taking a significantly longer time to do so (M. Bauman, personal communication, November 11, 2022). Agriculture was also a use case that frequently appeared, as traversing a wide area of farmland is a task more efficiently completed with the usage of a drone (T. Parisher, personal communication, November 11, 2022). Such a task can be completed for a relatively low price point, as it doesn't require the usage of specialized software or equipment. This also extends to real estate, construction, and other industries that require aerial photography or videography from a high-risk, high-elevation point.

Two of the institutions that we interviewed had experience with employing UAVs for security purposes. However, their final outlook on how worthwhile the investment has differed. It is important to note that NMSU received the drones as a donation after a student organization purchased them without realizing that university regulations forbade them from using them (New Mexico State University Representative, personal communication, November 9, 2022). CCC made the decision to invest in UAVs, meaning that they had the knowledge and preparations to support and properly utilize this investment (Cuyahoga Community College Representative, personal communication, November 14, 2022). Both institutions agreed that UAVs were useful during events in order to facilitate event security. However, most day-to-day tasks were more efficiently completed with security cameras, which cost less money and could be spread throughout the campus. The WPI representative had similar thoughts, stating that drones are akin to a tool, "but like any tool that you have at home, some tools are good for some things and they're no good for other things" (WPI representative, personal communication, November 18, 2022). Though WPI does not currently utilize drones on campus, the representative proposed that a possible use for them would be to inspect the roofs of buildings, which are normally dangerous

to access, reinforcing the idea that drones are best applied to scenarios where their specialized nature can be fully applied.

4.1.5 Staffing

This code also relates to the Economic PESTLE factor as staffing could be a large percentage of costs to a business. Therefore, the question of purchasing drone technology as DaaS may come down to whether or not a company will be able to reduce staffing costs in order to allocate funds towards the acquisition of the DaaS package, or whether the marginal benefit associated with acquiring drone technology is significantly higher than the additional marginal cost associated with hiring more staff.

A source of many issues for companies currently using drone technology is related to staffing. A major concern for drone companies is finding and hiring talented drone pilots, and a big question is always whether the use of drone technology will permit for less people to be on staff at any point in time, or if more people will be required to be on duty to oversee the proper use of the drones. When referring to drone pilots in the industry, Mark from Optelos says, “The really good ones are fairly rare, there’s a lot of very average ones” (M. Bauman, personal communication, November 11, 2022). Later in the interview, he states, “One of the biggest limiters right now, of adopting drone technology, is that you need drone pilots”, giving further insight to how difficult it is to find talent in the industry. During our interview with New Mexico State University, when discussing the University Police’s use of drones for routine surveillance and whether drone technology could decrease the amount of personnel required at any point in time, Chief Bowen mentions, “When it comes to staffing, we don’t have a large amount of staff

to dedicate to those types of operations, so it just wasn't very feasible for us" (A. Bowen, personal communication, November 9, 2022).

4.1.6 Regulations

This factor relates to the Legal and Political PESTLE factors because regulations play a large role in setting the rules that a business must play by in order to operate legally, and these regulations are put in place by politicians, lawmakers, and other significant stakeholders within the government.

US government regulations are an extremely important factor to consider when analyzing Robsense's potential for expansion into the US. When conducting interviews, the topic of regulations came up in every interview, with the most prominent regulatory organization referenced being the FAA. In our interview with Mark Bauman from Optelos, Mark mentioned that "drone pilots have to be FAA part 107 certified" in order to operate UAV technology (M. Bauman, personal communication, November 11, 2022). When referring to BVLOS regulations, Mark also mentioned that another drone competitor, Percepto, had recently gained permission from the FAA for nationwide BVLOS operations, further suggesting that companies with the ability to fly autonomously outside of the range of human pilots would be greatly beneficial for growth within the US drone market.

4.2 SWOT Analysis

The purpose of this SWOT analysis is to facilitate a review of RobSense and their position as a possible contender in the US Drone market by taking a closer look at RobSense's

experience and capabilities and analyzing any external forces that may affect RobSense's successes or failures as a business venture in America.

4.3.1 Strengths

RobSense has many strengths to attribute to the DaaS model, with one of the strongest being its experience with autonomous flights. During our interview with RobSense, when asked if RobSense's drones would have obstacle avoidance, automatic takeoff and landing, or other autonomous capabilities, the representative showed us a video of a drone that they built to do underground high-voltage powerline inspections and confirmed that the drone was operating fully autonomously with the use of a small lidar and a dual camera module. As we move closer to the future, the importance of autonomous drones becomes apparent in order to secure efficiency and safety during potentially life-threatening drone operations (Bajaj, 2022). RobSense's ability to conduct autonomous flights will surely be very useful for many consumers since many of them do not want to train and pay extra for experienced pilots when the drones could just be automated.

As we went forward with the interview, we were able to learn more about another strength of RobSense when the representative explained that "From our experience in China, most end users are not very experienced in drone technology, so in this case, we will provide the drone hardware, ground control software, data analysis software, and we will also send our pilots to help them integrate the components and provide hands-on operation" (RobSense representative, 2022). Being able to provide experienced personnel to either help with the operation or training of new operators is a major advantage for the company.

A strength that RobSense possesses is their access to the Chinese supply chain (RobSense representative, personal communication, December 14, 2022). This allows them to manufacture technology at a cheaper price per unit, giving them an edge over their competitors. For a company that specializes in hardware, this advantage allows them to better play to their strengths, potentially securing them a place within the markets of countries that lack cheap production.

Finally, as RobSense's ultimate goal is to expand into the U.S. market, having contacts or partners that are already located in the U.S. will be a major help. During the interview, the representative gave us a contact that is located in the U.S. we could talk to for information, called CraftTheoryLLC. This is a company that helps RobSense distribute its current hardware in the U.S. market. This can also be seen as a strength for RobSense since they are already partnered with a local company in the U.S. which sets up their further expansion into the U.S.

4.3.2 Weaknesses

A weakness that RobSense possesses is its lack of experience with sophisticated data processing software and AI technology. As a company focused primarily on producing hardware, they have only recently begun the development of its own digital twin asset creation software. Such software is important, as the storing and processing of data obtained from autonomous drones is highly valuable to companies employing UAV technology (M. Bauman, personal communication, November 11, 2022). Especially considering RobSense's goal of becoming a total solutions company, gaining familiarity with this software will be increasingly important. AI in drones is also growing relevant, as a common limiting factor within the drone industry is not the ability to collect data, but to store and process the data after it's been collected. At the

moment, however, they haven't fully developed any AI models for their drones, citing AI as being "very domain knowledge specific", as "Beginning the process of developing drone-related AI requires not only knowledge of UAV equipment, but also experts who have a strong background in the industry (RobSense representative, personal communication, November 27, 2022)".

A final inherent weakness of RobSense is the company is based in China. While expanding to other countries always carries the price of exporting goods and finding foreign workers, China and the U.S. have recently had a strained economic relationship, with both countries placing tariffs on goods from the other (Peterson Institute for International Economics, 2022), resulting in decreases in the import of hardware from China. This creates issues for smaller companies like RobSense, which will find difficulty in entering a now more expensive market.

4.3.3 Opportunities

The combination of a stable projection of growth in the UAV industry and the high rate of investment flowing into the sector creates opportunities for companies, like RobSense, looking to break into the market. The Boston Consulting Group estimates that by 2050, the combined drone fleet in Europe and the U.S. will generate $50 billion per year in revenue (Amoukteh, 2021). Due to its infancy, there is a myriad of challenges facing drone technology, with each presenting a chance for a solution to be developed and room for innovation. The opportunities present in the drone sector are an external presence uncontrollable by RobSense as they look to expand into the US, and these opportunities can be sorted and categorized with a PESTLE analysis, though it

must be qualified that there are not opportunities present in every area defined by this type of analysis.

Drones are projected to have a huge effect on the economy, providing certain industries with a cheaper source of unmanned labor (Pinnacle Digest, 2021). Industries such as agriculture and security are the primary benefactors of this, as tasks such as inspections and pesticide deployment can be completed at a much cheaper cost using UAVs. This technological advancement won't destroy jobs, however, as the jobs lost will be replaced by the positions necessary to operate drone technology.

Technologically, drones are poised to make existing solutions obsolete in a few industries. The ability to quickly cover large distances and scale to great heights allows drones to outcompete existing tools or services offered to complete tasks of visual inspection or surveying that would traditionally be done on foot or with lifts. With UAV technology constantly evolving and being developed, fully autonomous flight creates further opportunities for drones to create their own niche while becoming the best option in other spaces.

A significant benefit that UAV technology may bring is a reduction of carbon emissions. A study has revealed that drones were significantly more efficient when it came to delivering parcels when compared to trucks, releasing 84% less greenhouse gas emissions, while consuming 94% less energy (Kreier, 2022). A separate survey discovered that 60% of people would be willing to pay extra for this feature, as parcels delivered by drones would arrive significantly faster than their automobile counterparts. These benefits are the reason companies such as Amazon have begun looking into the usage of UAVs as an alternative for delivering packages.

4.3.4 Threats

When considering external factors that may decrease RobSense's chances of success in expanding to the United States, it is also important to consider any political, economic, social, technological, legal, or environmental factors.

One of the largest political concerns is the growing tensions between China and the United States. Recently, in October of 2022, "DJI found itself on the US Department of Defense's official blacklist for seemingly having close ties to China's military." (Dronedj, 2022).

DJI is the largest global producer of consumer drones and clearly opposes attempts to weaponize its products. DJI states that they "stand alone as the only drone company to clearly denounce and actively discourage the use of our products in combat, including suspending all business operations in Russia and Ukraine to try to keep our drones out of the conflict". However, when they joined the Department of Defense blacklist for being closely associated with the Chinese military, a new possibility of sanctions was introduced for the drone manufacturer. This is just one example of how growing tensions between the US and China could be a threat to RobSense's expansion and growth within US markets.

When considering economic factors, it is important to consider competition from other drone manufacturers and service providers. During an attempt to penetrate a new market, especially a technology market within another country, there will certainly be fierce competition from established companies that do not wish to give up a portion of their market share to another company.

Although not a major concern, some social factors that could threaten growth include potential dangers to public health and safety as well as fear of privacy protection and data security. These factors would not necessarily affect every application of drone technology but must be taken into consideration when considering a customer's drone service needs.

Technologically, there aren't many risks to drone hardware manufacturers or service providers apart from the competition from other companies. Companies such as American-based drone manufacturer, Skydio, pose strong competition to RobSense, especially in the development of drone hardware with autonomous 360-degree obstacle avoidance. RobSense faces a unique challenge, however, in choosing an “open-hardware” business model. This means that it is RobSense’s intention to make all of its designs and schematics publicly available for anyone to access, make changes to, and produce for themselves. While this strategy of keeping their work completely transparent may help with being accepted as a global company and may lead to fewer regulations and sanctions when expanding into new markets, it also may lead to other issues for RobSense, including loss of market share and security risks. For example, if all of RobSense’s designs are able to be downloaded, modified, and used for manufacturing, some of RobSense’s potential customers may simply begin producing their own drones without paying for the work that went into the design.

Finally, when considering legal factors that could affect RobSense’s ability to provide drone services in the United States, it is crucial to study the FAA regulations on BVLOS flights. According to Precision Hawk, another drone software solutions company, “In many cases, drones prevent humans from being placed in a dangerous situation, either removing them from an aircraft or a hazardous area. These areas can be inaccessible for a ground crew, and are often outside VLOS” (Ferguson, A, 2022). Obtaining waivers and FAA part 107 exceptions for

BVLOS has been historically very difficult, however, with “More than 1,200 applications to obtain BVLOS permissions have been submitted to the FAA already. More than 99% of these applications have been denied”. One of the reasons for the vast majority of BVLOS applications being denied is due to a priority on maintaining public safety. “The FAA’s main concern is uncontrolled flying that puts lives and vital infrastructure in danger. The agency must be assured that drones sharing the sky with airplanes will not result in midair collisions and that the risk of damage to people and property on the ground is mitigated” (Choudhary, M, 2019).

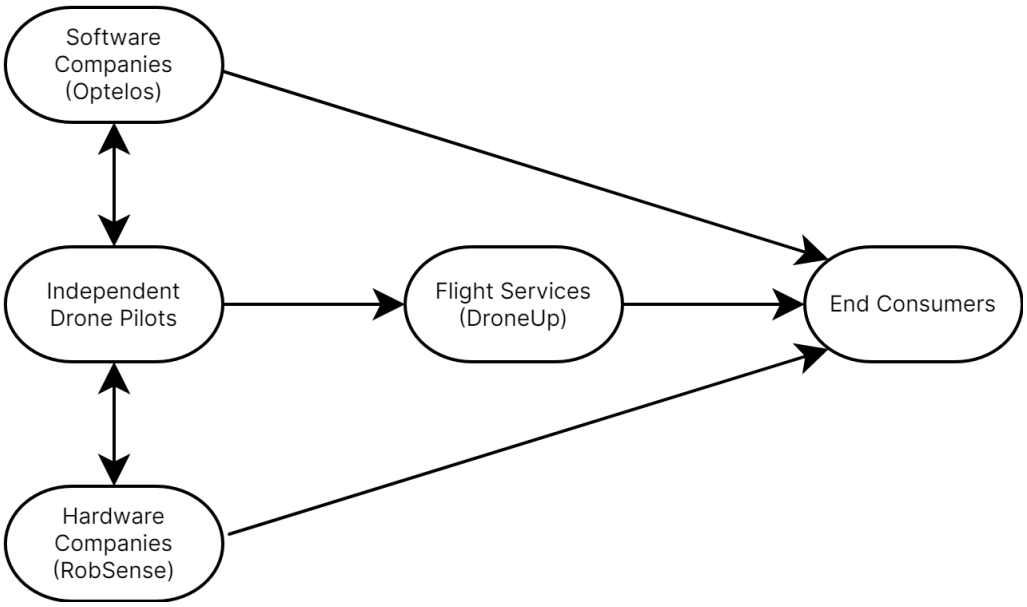
4.4 Findings

Based on our secondary sources, it is clear that UAV technology is very much relevant to the future of many commercial industries. The specialized nature of drones allows them to fulfill roles that are either too dangerous for people to perform or too expensive to complete using traditional methods. As time goes on, more autonomous software for drone technology will be developed, increasing the efficiency with which these tasks are completed.

It is also clear that marketing drones using an as-a-service business model is a viable business strategy, as it addresses the biggest limiting factors for companies seeking to invest in drone technology for their business. These factors include the large price point that comes with purchasing drone technology, an issue solved by the cheaper “subscription style” pricing of the as-a-service model, as well as the training and experience required to operate UAV technology, which is solved with the inclusion of trained operators or drone flight instructors within the service package. Other services included in the package, such as software/hardware updates and drone repairs are incentives to invest in the package, as the alternative of replacing or updating equipment is often too expensive to be sustainable for smaller companies.

The U.S. market is a good opportunity for RobSense, as most companies working in the region have expressed a willingness to develop partnerships with other companies. Though RobSense aims to become a total solutions company, many of the larger drone companies in the U.S. have formed an ecosystem, with different companies contributing different services (see Figure 2).

Figure 9: Drone Ecosystem



Note: An example drone ecosystem that RobSense could potentially be a part of

Within this ecosystem, RobSense could contribute drone hardware, as they have specialized in drone swarm link technology. DroneUp doesn't manufacture their own drones, purchasing them from a separate manufacturer before modifying them for specific uses. This is but one of many potential openings that RobSense could fill within the ecosystem. However, inclusion into this ecosystem is not necessary in order to expand into the U.S. Pursuing their original goal as a total-solutions provider is still viable, as the drone industry within the U.S.

isn’t dominated by any select few companies, instead being perpetuated by a variety of varying companies.

Despite this, expansion into the U.S. is still difficult, primarily due to their strained trade relationship. While it is still quite possible for Chinese companies to find success working in the U.S., these factors mean that RobSense may find greater difficulty in expanding to the U.S., especially when considering the competition from already established companies such as Skydio and Boeing. Implementing an as-a-service model also introduced additional difficulties, as RobSense must now supply trained operators and equipment to a foreign country. Whether they accomplish this by sourcing new pilots or relocating currently existing ones, there will be additional expenses associated with this course of action.

5. Conclusion

In this section, our team reflects on the project and the process that we established to complete it. Following our reflection, we present our recommendations to our sponsor based on the information collection and analysis.

5.1 Project Retrospective

For the most part, this research project went as smoothly as we had hoped for. Before the start of the second term, our team created a Gantt chart in order to help track our progress, letting us know when we were behind schedule. During the term, the chart made us aware of when certain aspects of the project, such as scheduling interviews or organizing collected data, were close to hitting their projected deadlines. Because of this, we were able to adjust our workflow accordingly.

Our primary research method was the most uncertain part of our research. At the start of the project, we were able to find many articles discussing the various aspects of drone technology and its commercial applications. However, whether or not we secured interviews was dependent on our own ability to reach out to related companies. In the end, we were able to secure the interviews quite quickly and wrapped up that phase of the project within the projected period. Though we only managed to secure 6 interviews, we were able to meet with a somewhat varied selection of companies, facilitating our goal of identifying the profitability of drones within different industries.

5.2 Recommendations for RobSense

By interviewing various organizations and conducting secondary research, we were able to discern some key takeaways regarding the current state of the overall drone industry as well as the feasibility of RobSense becoming a drone hardware design and manufacturing company or becoming a total solution drone-as-a-service provider. Our takeaways were based on the US market, but they express similarities shared by our partner team from HDU whose recommendations were based on the Chinese market. A comparative summary of the WPI and HDU teams' recommendations can be found in Appendix E.

Within the United States, marketing drone technology using an as-a-service business model is profitable. This is due in part to the expensive nature of drones, the speed at which drones can be deployed and utilized, the advantages of being able to record data as well as create digital twin assets such as point cloud maps or meshes, and the ability to remove humans from potentially dangerous environments. Thus, it is viable for RobSense to enter the United States drone market as a total solution DaaS provider, as the benefits brought by such a business model

have the potential to create immense value.

This also comes with the recommendation, however, that serious effort is put into either the internal development of digital twin asset creation software or the formation of a partnership with a company that can provide digital twin asset creation software. These technologies have shown themselves to be vital to the success of any DaaS provider. When compared to previous methods of taking notes during inspections, access to digital twin assets such as point cloud maps, meshes, and voxels allow companies to visualize their data in a way that is more accessible and monitorable across a large period of time.

While this technology may not be inherently difficult to develop, We believe that forming partnerships with existing companies within the United States will be a very strong strategic move for increasing chances of success in the US market. Companies such as Optelos can provide data collection, storage, analysis, and AI solutions and companies like DroneUp can help RobSense find high-quality FAA certified drone pilots to complete jobs in the US. This would allow RobSense to focus their efforts on the development of quality drone hardware and payload solutions.

Another aspect of our recommendation to RobSense is to place a high importance on attempting to obtain an FAA part 107 BVLOS waiver. Although not necessarily critical to RobSense's success, obtaining a BLVOS waiver from the FAA will be very important for RobSense's ability to conduct sophisticated autonomous flights outside of the range of visual line of sight. As we can see from our secondary source research, obtaining these waivers may prove to be difficult. We recommend researching which factors lead to increasing a company's chances of obtaining BVLOS waivers.

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7. Appendices

Appendix A - List of Contacted Companies

Worcester Polytechnic Institute
Hawai‘i Pacific University
Grambling State University (https://www.gram.edu/aboutus/contact/)
Colorado State University
Cuyahoga Community College
Lehigh University
New Mexico State University
Northwest Florida State College
Pennsylvania State University
University of Alabama in Huntsville
Ohio State University
University of California Berkeley
Michigan State University
Navigat
Granite

Criterium Engineers (https://criterium-engineers.com/)
TRC Companies (https://www.trccompanies.com/services/field-services-inspection/construction-inspection/)
NorthWest Construction Control (https://trynorthwest.com/)
KCI (https://kci.com/services/construction-management/construction-inspection/)
Inspection Services Inc. (https://www.inspectionservices.net/)
Construction Engineering and Inspection (CEI) - S&ME
InterTek
Lauring Construction
Opletos
Kinectrics
Mistras Group
DEKRA
Infraspect
ARE Infrastructure Inspection
Volkert
Stantec
Bechtel

Pinkerton
Inter-Con Security
On Guard Security
Allied International Security (https://alliedintsecurity.com/)
American Hawk Security (https://www.americanhawksecurity.com/)
United Guard Services (https://www.unitedguardservices.com/el-cajon-security-guards)
Security USA (https://www.securityusainc.com/)
Delta Five Security (https://www.deltafivesecurity.com/)
Citadel Security (https://www.citadelsecurityagency.com/new-york-event-security/)
API Security (https://www.apisecurityinc.net/)
Safety Zone Security
Safeguard On Demand
Scaife Protection Services
Overtime Security & Consulting
Atlas Protection Solutions
ASC Private Security
Schlumberger
Halliburton

Weatherford
China Oilfield Services Limited
AVANGRID (The United Illuminating Company)
Algonquin Power & Utilities
PacifiCorp
NRG Energy
NextEra Energy
ConocoPhillips
Chevron
ENTERPRISE PRODUCTS PARTNERS
TC ENERGY
KINDER MORGAN
WILLIAMS COMPANIES
ENERGY TRANSFER
ONEOK
General Electric (GE)
Clipper Windpower, LLC
AllEarth Renewables

Sangster Group, LLC
Heartland Energy Solutions
Eastern Wind Power, Inc.
Supreme Gear
Vestas
Kiewit
Newmont Mining Corp
Peabody Energy Corp
Arch Resources
SunCoke Energy
Alpha Metallurgical Resources
Consol Energy
Compass Minerals International
US Silica Holdings
Coeur Mining
Freeport-McMoRan
Southern Copper
Droneup

United Rentals
Connexicore
Aerodyne
Cyberhawk
Terra Drone
Zipline
Yuneec
1Up Aerial Drone Services
Public Storage

Appendix B - New Mexico State University Interview Questions

1. It's our understanding that you have used UAV or drone technology in the past for security and surveillance purposes at New Mexico State University and have since then stopped their use. Is this accurate?
2. How many months were the drones in active use on campus or in surrounding areas?
3. What was the method of obtaining the drones? (Purchased, Leased, Rented, etc.)
4. How much did it cost to acquire the drones this way?
5. How did that technology help with the drones?
6. Why did you stop using drones?
7. Did you think it was necessary for drones to be used instead of some already used security functions before you acquired the drones?/ Did you expect that drone surveillance would have more advantages over traditional monitoring and security patrol?
8. Not Useful → If there were more features to the tech, would it have been more useful to you?
9. Did you think if the drones had those features would your police department be willing to pay for them?
10. Cost → If there was a DAAS available to enable you to use drone technology
11. Did you think of using drones to do patrols/routine work?
12. Any closing thoughts on the drones?
13. Would a private business be able to offer and provide tools to a police department?

14. In addition to your existing features, what else would you want drones to do for it to be more useful?/ What are the advantages of drones that make you feel particularly useful?

15. If there was UAV inspection system suitable for your university, do you think the number of security guards can be reduced accordingly? If it can be reduced, how much less people could be hired?

Appendix C - Cuyahoga Community College Interview Questions

1. It's our understanding that you have used UAV or drone technology in the past for security and surveillance purposes. Is this accurate?
2. How many months were the drones in active use on campus or in surrounding areas?
3. What factors led to this decision to utilize drone technology?
4. What was the method of obtaining the drones? (Purchased, Leased, Rented, etc.) How much did it cost to acquire the drones this way?
5. How are drones currently being implemented by the university?
6. There is an issue being encountered by the police department/college.
7. How have drones outperformed other ways of completing these tasks (ie: why are you still using drones?)
8. Have issues regarding drone applications and drone flight restrictions?
9. Cost → If there was a DAAS available to enable you to use drone technology
10. Would a private business be able to offer and provide tools to a police department?
11. In addition to your existing features, what else would you want drones to do for them to be more useful?
12. Any closing thoughts on the drones?

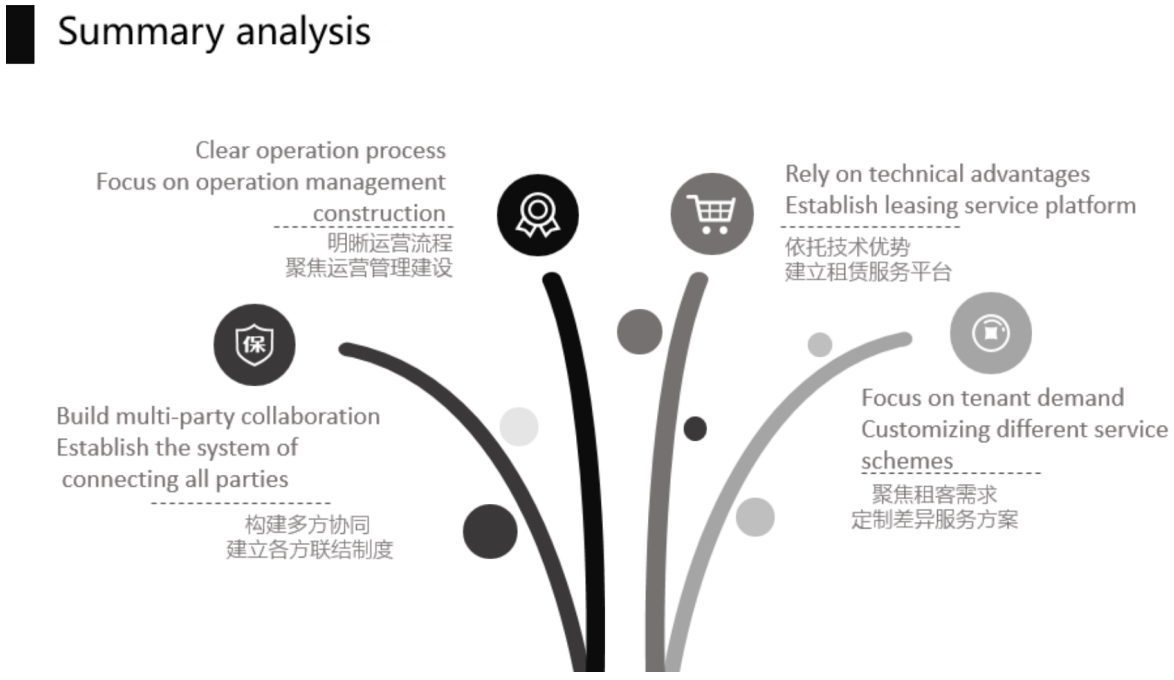
Appendix D - Optelos Interview Questions

1. Optelos has a thorough vertical integration in the services that they provide. Is there a particular service that you offer more often than others?
2. Do your customers typically have their own drones/pilots, or do you often have to provide your own resources to collect data?
3. How do regulations affect the flight of your drones, if at all?
4. Are your drones or the drones that you work with typically controlled manually or do you also implement AI flight technology, such as SLAM and/or VIO?
5. How much do you charge for each aspect of your service?
6. How much are the components of the service you offer?
7. What are the existing alternatives for customers, if they don't use your services?
8. Do you own the drones that you use or lease them from someone else?
9. Do you offer to sell or lease your drones, or just the services that they provide?
10. When a drone is damaged, what is the average cost of repair?
11. Do your customers ever express an interest in owning drones themselves?
12. Are there any services that customers ask for and you are unable to provide at this time?
13. Are your pilots stationed in various spaces around the country to make accessibility easier or do you have to have them travel for each project?

Appendix E - Interteam Comparative Analysis

The WPI and HDU teams worked in tandem to offer recommendations to RobSense, with each team focusing on the drone market in their respective countries. This was done to facilitate the collection of information and allow for a comparative analysis to observe similarities and differences that exist in the conclusions of each team. Both teams created their recommendations based off of interview data that they collected, with each team's recommendations for RobSense being catered to the country in which their portion of the project was focused. The HDU team's findings corroborated those of the WPI team, even though the final recommendations by each team do not share explicit similarities in offering recommendations that are the same.

Figure 10: HDU Summary Analysis



Note: This graphic shows the HDU team's recommendations to RobSense as they were presented in one of their presentations.

The HDU team constructed their recommendations to reflect the current strengths of RobSense and highlighted adapting the company's DaaS offerings to fit whatever unique needs a client could have. Both teams suggested that RobSense form partnerships and collaborate with other entities or companies in order to reach its goals, however, this suggestion appears to be made with slightly different reasoning in mind from each of the teams. Building relationships with companies in China would give RobSense more local leverage, and these bonds could also be easier to form due to their geographical proximity. Building relationships with companies in the US would strengthen RobSense's position overseas and potentially give it a means to work through tariffs and trade regulations. The WPI team's recommendation to partner with a software company, such as one in the US, is founded based on the prevalence of data analysis services being recommended in interviews that the team conducted. All things considered, both teams conclude that the DaaS business model presents itself as a viable method to expand RobSense's operations and allow it to compete effectively in foreign and domestic markets.