TEAM GRYFFINDOR BUSINESS PLAN

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Neha Goel, Anika Puri, and Anvi Datta

VFLY ~ A Novel Solution for Prevention of Avian Fatalities from Human Obstacles using Bird Species Identification with Artificial Intelligence

Conrad Challenge Semifinalists in Energy & Environment 2017 - 18

Video Pitch: https://www.youtube.com/watch?v=XjEL8MQfOT8

I. Company Introduction

We are Team Gryffindor, from Chappaqua, New York. We are a group of young, enthusiastic middle/high school girls who aspire to to help the world using our STEAM skills. Neha and Anika met at a STEM Competition as competitors. With our mutual interest in science, we decided to form this team. We decided to use the skills that we have learned working together as a team to develop our product, VFLY. We have specific roles for each one us. For example, Neha was the Chief Operating Officer (she coordinates the team, communicates with professionals). Anvi played the role of the Chief Finance Officer (She analyzed various market segments, determined sales estimates etc). Anika is the Chief Technology Officer (She is our IBM Watson expert).

All of us are avid bird lovers, and started investigating the issue of avian mortality due to collisions with human obstacles after watching multiple birds hit our schools windows. With our scientific curiosity, and technical acumen, we were able to combine leading edge technologies such as Artificial Intelligence and Internet of Things to solve a real world problem impacting the ecosystem we live in.

As we developed our idea, we had to learn programming, and assemble hardware components. We even were able to custom train IBM Watson to improve its recognition of bird species images. When we presented our idea to IBM experts, they decided to feature our code on their education curriculum.

Working with multiple chapters of the Audubon Society, we learned about different species of birds, and how their populations were declining. Given VFLY's potential to save bird lives, New York City Audubon Society has invited us to speak at one of their conferences later this year.

Outdoor field testing was one of the more interesting and challenging aspects of our product development. After multiple frustrating attempts, we were able to adjust our devices sensitivity to correctly capture bird images. We had multiple visits to local nature preserves to observe and test our device, even in cold winter nights.

II. Business Prospectus

a. Business Description:

Over a billion birds die each year due to collisions with human obstacles, such as windows and communication towers. Windows kill over 900 million birds annually (Figure 1), while tower kill puts 52 bird species on the Bird of Management Concern List. Already, ⅓ of all North American bird species require urgent conservation action (Figure 2). Birds are incredibly valuable as they aid agriculture by slowing the spread of diseases and pests-- services valued at over $5000 per square mile.

Figure 1. Human Causes of Bird Deaths In the United States

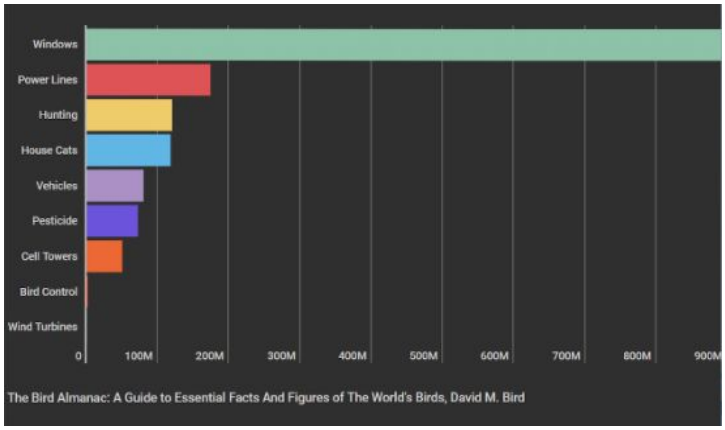
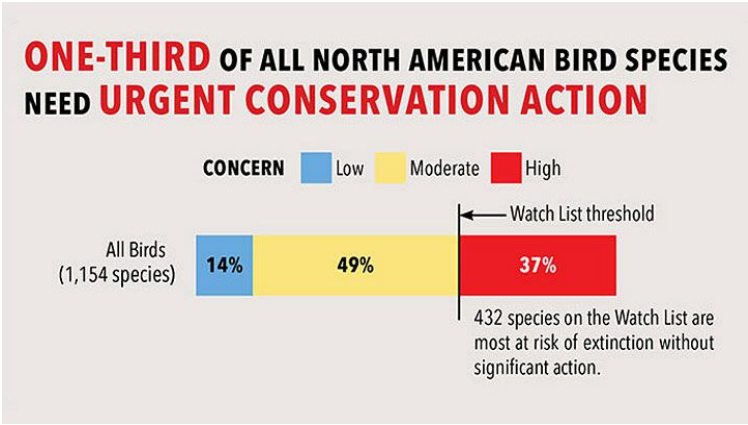


Figure 2. Species Requiring Urgent Conservation Action

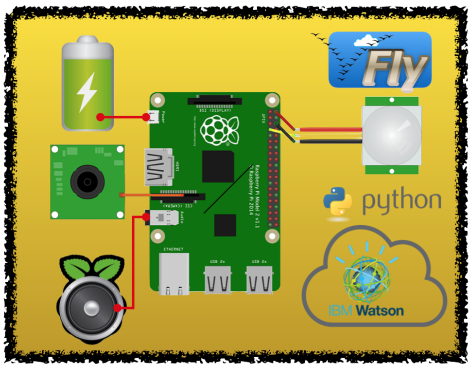


Bird enthusiasts have been advocating the use of sound alarms and ultraviolet decals to deter bird collisions. However, sound alarms fail to play audible, timely, and biologically relevant sounds, rendering them ineffective. Ultraviolet window decals costs can be very high, estimated to be $60 million in some instances (Viking Stadium).

We developed a solution called VFLY, which utilizes species-specific predator calls to scare birds away from danger. The device can be placed at homes, building or stadiums where extensive bird collisions have been observed.

The device has four main components: motion sensor, camera, visual recognition software, and speakers (Figure 3).

Figure 3. VFLY Schematics



The motion sensor will detect a bird flying towards it, triggering the camera to capture an image. The visual recognition system will identify the bird species from the image. Based on the species identified, the device will play a specific predator sound. This will make the bird fly away, saving its life!

Our device plays audible (due to the speaker), timely (due to the use of the motion sensor), and biologically relevant sounds. Our use of a visual recognition software is the most unique aspect, allowing for VFLY to play relevant sounds

based upon species. Therefore, VFLY is much more effective in scaring the birds away from windows, towers, etc.

Since VFLY is a programmable device, we can extend it for uses in multiple industries. Since it can recognize bird species, we can customize its behaviour accordingly.

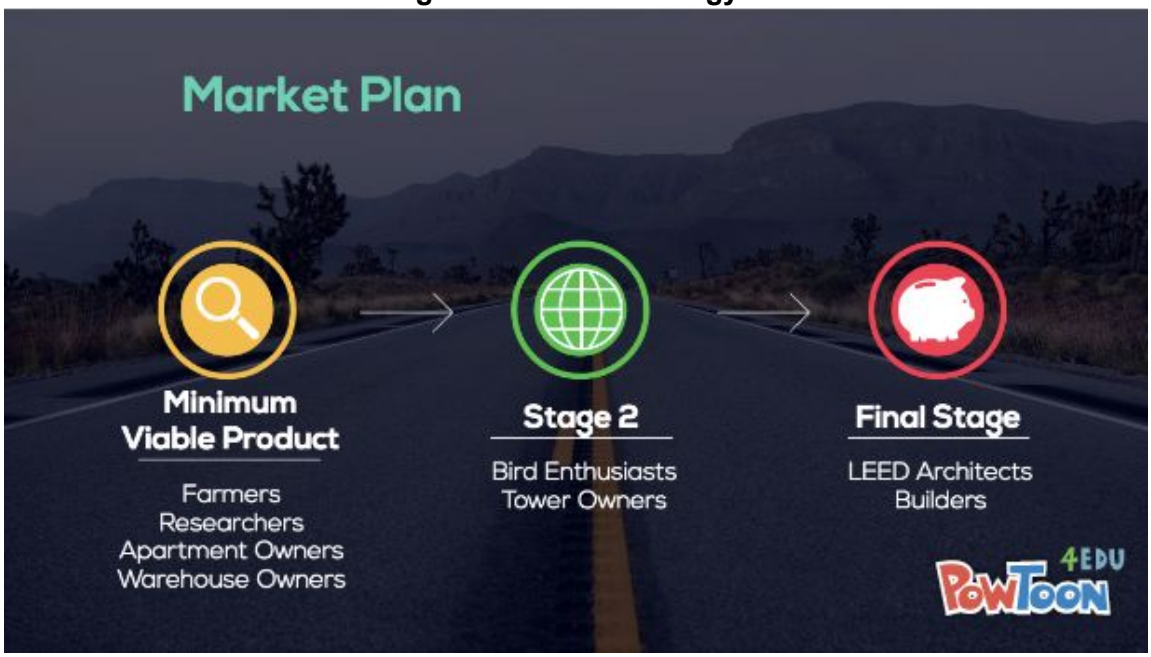
As awareness of this huge problem increases, builders are facing tremendous pressure to implement bird-safety measures and design environmentally-friendly buildings. We intend to make VFLY part of the Bird Deterrent Pilot in the LEED Building Certification. Actually, according to the prominent LEED architects we consulted with, the Bird Deterrent Pilot is one of the most fast-growing and popular pilots of the certification. By making VFLY compliant with the certification, we will increase our market, making our business more successful.

Homeowners and builders shy away from installing window decals because of costs to retrofit, as well as aesthetics concerns. VFLY is very cheap and compact, maintaining the building's look. VFLY is programmed to be extremely user-friendly, with mobile app based configuration for loudness, schedules etc. Notifications of rare bird species can be sent to bird enthusiasts. By understanding the needs and providing additional features, we will be able to capture the market of builders/homeowners and guarantee the success of our business.

b. Market Analysis:

While our original goal was to save birds, VFLY's adaptability made it the perfect solution for other markets where bird control is needed. We have developed our market strategy (Figure 4) We intend to start marketing our product to these segments to fund the full development of VFLY

Figure 4. Market Strategy



i) Minimum Viable Product: With our current prototype, we have all the performance specifications to sell to researchers, farmers and warehouse/apartment owners.

Researchers: VFLY would be very useful to researchers to determine bird migration patterns, and bird populations counts in various regions. This aspect was particularly exciting to the ornithologists that we have presented to. To raise awareness of our product in the scientific community, we will creating a database with all the data/pictures VFLY has collected on bird species and presenting to various ornithologist societies.

Farmers: While most birds aid agriculture, some bird species ruin farmers plantations and crop fields. Millions of farmers use netting, which is way too costly ($400 an acre) and prevents all bird species from entering. VFLY is especially innovative since it can scare away birds that are ruining crops, without impacting birds that help farmers with pest control. In the US, there are 2.2 million farms and there are more than 570 million globally, a huge market for VFLY. We will market by joining farming associations, giving presentations at events, and placing ads for our device in farming catalogs.

Warehouse and apartment (balcony) owners: VFLY can also act as bird pest control. Bird dropping cleanup solutions are costly, nettings are intrusive, and sound alarms ineffective. There are 10,000 warehouses and 2.25 million apartment complexes in US alone where VFLY can be used.

II) Second Phase: After accomplishing Watson latency requirements, we can target bird enthusiasts and tower owners.

The Audubon society claimed that all their members would love to buy our product. There are over 47,000,000 people registered as birdwatchers. They spend $41 billion annually on birding trips and $6.3 billion on bird feeders, and would be willing to buy VFLY to prevent bird deaths. We will market by placing ads in Audubon/Ornithologist societies' newsletters/catalogs, websites, social media, and bird magazines.

There are 215,000 towers in the US currently. Legislation has been passed demanding that communication towers be placed certain distances away from bird environments. Additionally, tower owners spent millions in clean-up costs each year. We will market to tower owners through presentation given to specific companies and organizations.

III) Third Phase: After working with LEED designers to make VFLY part of the certification, we will sell our device to building owners. The LEED certification certified 800,000 projects worldwide. Additionally, the bird deterrent pilot is the most popular pilot. Builders wanting to gain the incentives of the LEED certification can install our product on their buildings.

Figure 5. Break Even Analysis

Fixed Costs	$200,000	Based on Industry Estimates of similar product developments (R-Style Lab)
Variable Cost per Unit	$30	Material costs estimates per unit
Unit Price	$70	Market Price of each vFly unit
BREAK-EVEN POINT	**5,000**	**NEED TO SELL 5000 UNITS ANNUALLY**

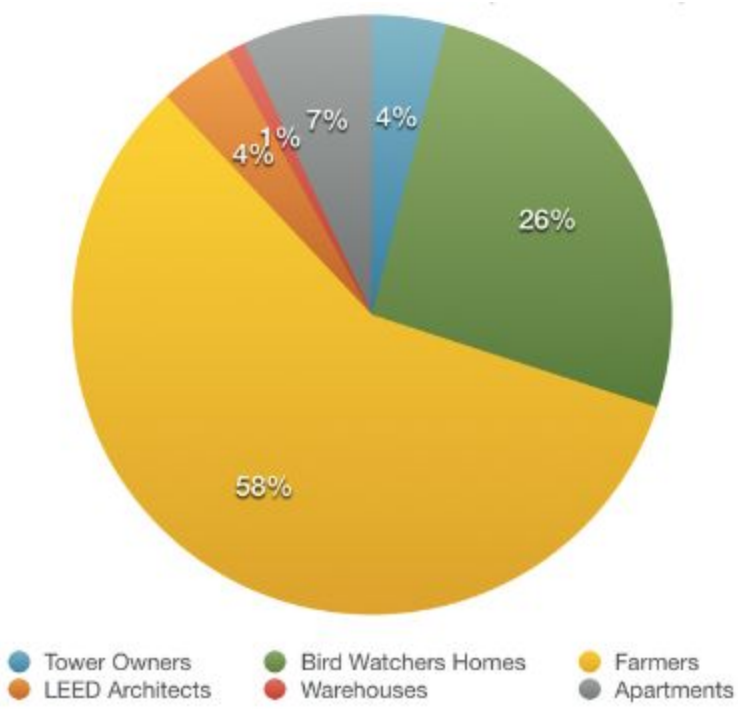
Figure 6. Sales Estimates

Market Segments	Total Size	Estimated % 1st Yr	Number of Units (1st Yr)	Number of Units (2nd Yr)	Number of Units (3rd Yr)
Tower Owners	150,000	0.5%	750	825	910
Bird Watchers Homes*	10,000,000	0.05%	5000	5500	6050
Farmers	2,200,000	0.5%	11000	12100	13310
LEED Architects	80,000	1%	800	880	968
Warehouses	46,000	0.5%	230	253	278
Apartments	2,250,000	0.05%	1125	1238	1361
			18905	**20796**	**22877**

*Size from National Survey of Fishing, Hunting and Wildlife-Associated Recreation Report

With 5 out of 10,000 bird watchers buying VFLY, we can cover costs for producing VFLY

Figure 7. Revenue Stream Breakdown (Within 3 Years)



c. Competitive Analysis:

Current solutions to solve this problem include window decals, ultrasonic sound alarms and nettings.

Window decals are strips of ultraviolet material placed on windows making glass visible to birds; however, homeowners are reluctant to use them as they are very visible and annoying. For skyscrapers, installing decals on all windows is very expensive. Studies show that birds do

try to maneuver around the window decals, but might fly right in between the decals, striking the windows. Different interior/exterior lighting conditions also make these decals ineffective.

VFLY is very compact, not interfering with the look of a house/skyscraper. Since VFLY will prevent birds from approaching in a general direction, all windows do not have to be modified, making it an inexpensive solution.

Sound Alarms use sound to scare birds away from windows or towers. Dr. Robert C. Beason's "What Can Birds Hear?", scientific article states -
"One category of deterrent/dispersal techniques is sound. To maximize their effectiveness these sounds that are used must

1. Be loud enough to be audible to the birds
2. Be within the frequency range the birds' ears can detect, and
3. Provide a timely biologically relevant message such that the birds depart

These sound devices play alarms at a frequency undetectable to humans. Since bird hearing range is roughly the same as humans, these devices are ineffective. Also, these devices play sounds at regular intervals and birds get used to them.

Our device meets all the above criteria, making it an unique and effective solution in this field.

Firstly, we have created an algorithm, which will take the average volume (in decibels) of a species' predator's call and the distance the bird is from the human obstacle, to compute how loud the predator noise should be played, ensuring that the sounds will be audible.

Secondly, all the predator calls played will be within the bird's hearing range. Birds are the most sensitive to sounds between 1kHz and 4kHz.

Use of a motion sensor will ensure that the sound is played in a timely manner, as a bird is approaching.

Lastly, we can ensure a biological relevance to the sound by playing predator sounds based on bird species. Visual recognition software identifying the bird species is the most unique aspect of our solution making the device very effective in scaring birds away. VFLY can be programmed depending on region, season, and time of day, which makes VFLY more adaptable.

There are no solutions to address the tower kill problem. Studies show that blinking lights are only up to 50% effective. Our device offers a cheap and effective alternative to scare away birds lured by the lights.

VFLY can be placed on all structures and will benefit builders of skyscrapers, communication towers, stadiums and individual bird enthusiasts. VFLY installations would be an inexpensive solution to make buildings/towers/stadiums more bird friendly. In addition, VFLY will help prevent clean up and window damage costs.

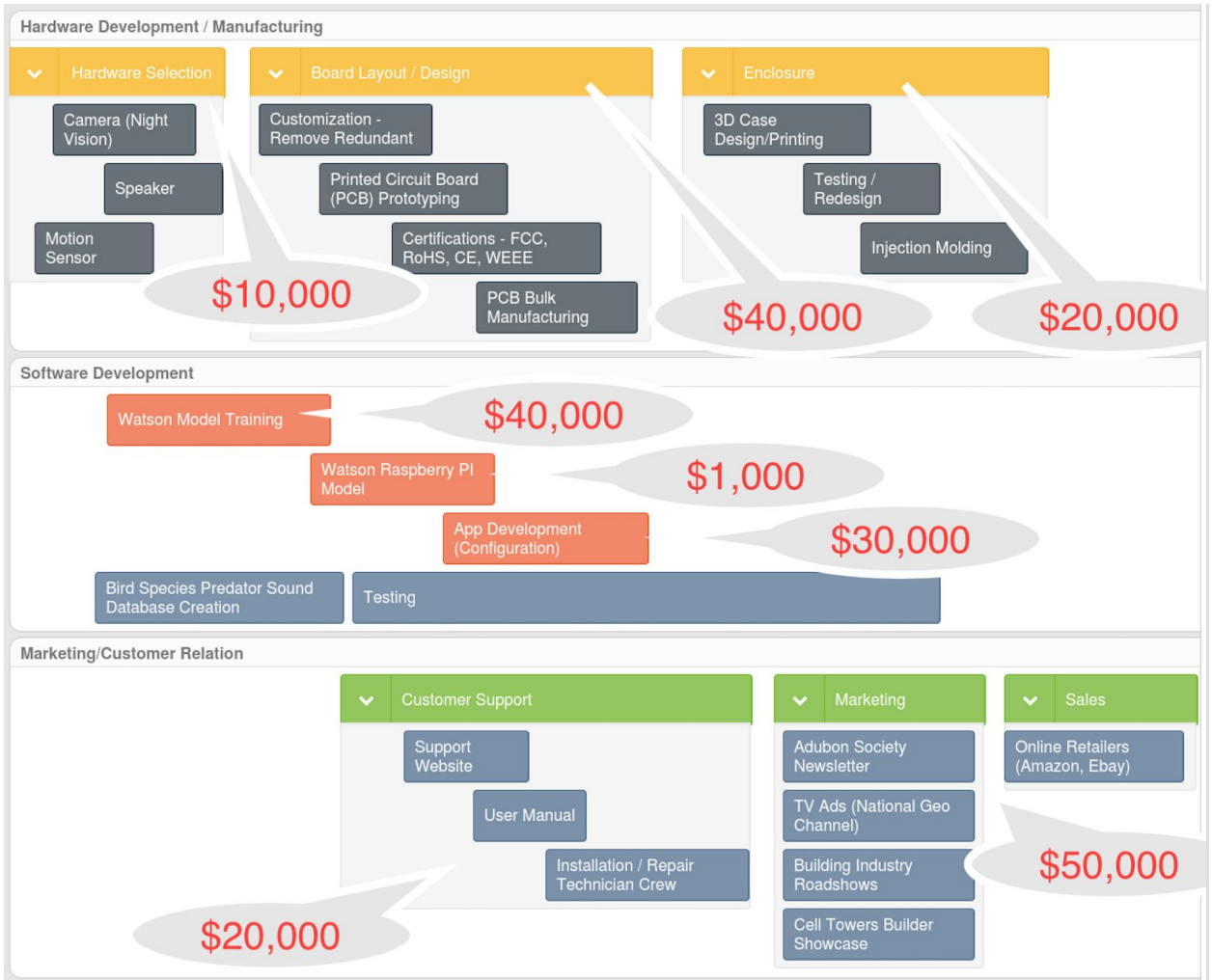
d. Cost:

Our current prototype costs $77 (Figure 8). However, after bulk production, we estimate the production of each unit to be $30, while we will set the retail price for the customers at $70. However, the cost of developing, marketing, and manufacturing VFLY is approximately $200,000 (Figure 9)

Figure 8. Prototype Costs

Component	Cost
Raspberry PI	$35
Camera	$20
Speaker	$10
Power Pack	$10
Motion Sensor	$2
Prototype Cost	**$77**

Figure 9: Plan for Creating, Operating, and Marketing VFLY



Below is the breakdown of all of our expenses:

1. HARDWARE DEVELOPMENT - $70,000

Hardware Selection - $10,000

We have identified specific performance requirements for our components. We will purchase different models of the camera, speaker, and motion sensor. These models will have to undergo rigorous testing to determine the ones suitable for VFLY.

The cost breakdown includes the price of purchasing materials and testing.

Board Layout/Design - $40,000

To reduce costs and increase compactness, we will be designing our own printed circuit board (PCB). Our PCB will contain only the necessary components for VFLY's hardware system and remove unnecessary parts from the Raspberry Pi. We will consult with companies that offer PCB services, such as Predictive Designs.

Since VFLY is an electrical device, we will have to obtain regulatory certifications. To obtain these certifications (ex. FCC, RoHS, CE, WEEE), we will have to conduct testing and demonstrate our device is compliant with the specifications.

Once our PCB is designed and we have received all of the certifications required, we will be utilizing the Raspberry Pi Customization Service, a cheap and efficient bulk manufacturing service.

The cost breakdown includes PCB consultation fees, certification testing, and price of bulk manufacturing of 3,000 circuit boards -- obtained through industry experts and computer research.

Enclosure - $20,000

To ensure VFLY's functionality in all weather conditions, we will design various models of weather-proof cases. We will conduct tests to determine the best fit design and modify our designs to incorporate new features.

We will use injection molding, a highly efficient and cheap process, to manufacture our enclosures after the design is finalized.

Cost breakdown includes the price of producing, via 3D printing models, our case designs, testing, following redesign, and injection moulding of 5,000 finalized enclosures.

2. SOFTWARE DEVELOPMENT - $71,000

Watson Model Training - $40,000

We have already successfully demonstrated Watson's model-training ability and will continue to train for more species of native birds as we conduct further testing. Scientists claim that there are 9,000 to 10,000 bird species and our goal for Watson is 8,000. To accomplish this goal, we will need to train Watson to recognize these species.

The cost breakdown is based upon our calculations with the cost of Watson API depending on images and the expense of hiring staff to conduct Model Training.

Watson Hardware Model - $1,000

Watson will have to return with the image classification in ⅛ of a second. IBM Watson experts have validated that this latency target can be achieved by putting the Watson Model on our CPU. This will also eliminate the need for WiFi.

Our Watson Hardware Model expense estimates comes from Dr. Ruchir Puri, our IBM Watson Mentor.

App Development/Bird Predator Sound Database - $30,000

We will have an external company create the initial app with features to appeal to our bird enthusiast market (such as the image gallery). Additionally, we need to further develop our predator sound database to include thousands of species.

Cost are based of typical software projects of this complexity.

3. MARKETING/CUSTOMER RELATIONS - $70,000

Customer Support/Installation & Repair Crew - $20,000

To ensure a streamlined installation process, we will be developing our customer support departments and installation & repair crews.

Our initial cost estimate includes the expense of paying salaries to the local workers we will be hiring for short amounts of time. As our business expands and ventures in foreign and national interests, we will expand our departments heavily with the revenues gained.

Marketing/Sales - $50,000

We will market our idea through Audubon Society catalogs/newsletters, TV ads on relevant channels such as National Geographic, Building Industry Roadshows, Cell Towers Builder Showcases, and Farmer Magazines. We will hire a few people to maintain our positive presence on social media accounts such as Facebook, Twitter, and Instagram.

We allocated lots of our money to marketing as we feel that it's important to raise awareness in society about VFLY to gain revenues even though we have large market segments.

Innovation Summit Travel Budget : With 5 people attending the Summit, we estimate a cost of $4325 (Figure 10).

Figure 10. Innovation Summit Costs

	Cost	Qty	Days	Total
Airfare	400	5		2000
Hotel Room	150	2	3	900
Meals	75	5	3	1125
Local Travel (Estimated)				300
Total				4325

e. Funding Sources

We've identified multiple funding avenues to finance VFLY.

- **Grant Money.** Our project will be able to be funded through grants from multiple organizations. Firstly, we already presented our project to the prominent board members of the New York City Audubon Society (Figure 11). The NYC Audubon is an

Figure 11. Presenting for the NYC Audubon Society

bird enthusiast organization that works for the conservation of bird species and nature and is one of the largest organizations in the Audubon movement with an upward of 10,000 members! Immediately, after consulting, the Audubon Society expressed great interest in our idea, giving us the opportunity to speak at their conferences and will be featuring us in their newsletters for our work. We are actively working with the Audubon Society on possible grants to fund VFLY. We have identified grant opportunities at organizations working towards preserving endangered species, including the

  - Fund for Wild Nature Grants,
  - World Wildlife Fund,
  - Shell Foundation Grant (working to restore critical ecosystems)
  - Terra Viva Grants

Additionally, other ornithologist societies offer grants for bird research as well, such as the AFA Avian Research Grant, Angus Gavin Migratory Bird Research Grant, Bill Terrell Avian Conservation Grant, Bloom-Hays Ecological Research Grant. The government offers grants

through the US Wildlife & Fish Service, which spends over $250 million annually funding projects to conserve animal species.

- **Award Money.** Similar to grants, we are constantly on the lookout for opportunities to enter our project in competitions to compete for prize money to further develop our product. For example, our team already had the honor of being awarded 2nd place in the Global Innovation Awards out of more than 20,000 teams globally. This prestigious award came with $5,000 to continue our pursuits. We plan to keeping entering VFLY for awards in order to raise funds.
- **Crowdfunding.** Crowdfunding is an important funding avenue. We will launch Kickstarter and GoFundMe campaigns with goals of $10,000. To actually gain funds, we will spread the word through friends and family, as well as give public presentations in our local towns and New York City. We will maintain active social media accounts to gain awareness.
- **Company Sponsorship.** Since our device uses IBM Watson API for species identification, we are looking to IBM Watson for company sponsorships. We met with Dr. Matt Hill, an expert on IBM visual recognition (Figure 12). Additionally, we will be presenting our idea to the entire IBM center soon. IBM Watson's sponsorship will give us access to invaluable initial funding as well as leading experts in the field

Figure 12. Consulting With Dr. Matt Hill

- **Revenues.** We've developed an innovate market strategy as we will be selling our product at different stages of development. Our current prototype, designed with a Raspberry Pi, has all the specifications needed to sell to researchers, farmers, and apartment/warehouse owners. We have already conducted extensive testing to prove the functionality of VFLY and Watson API. Therefore, we could sell our Minimum Viable Product. We will be able to receive sufficient revenues to fund for the further development VFLY to suit the latency requirements for selling to bird enthusiasts and tower owners. As a result, our product will be partially **self-funded**.
- **Ornithology Exchange Funding Portal.** This platform informs and provides bird researchers with different funding opportunities in the form of scholarships, grants, fellowships, and awards.
- **Private Investors.** We would like to partner with wealthy influential people who have shown philanthropic interest in conservation of bird species. We will conduct research, make conduct, and deliver promising pitches to these such people.

Funding for Travel Costs for The Innovation Summit: To raise money, we will launching crowdfunding campaigns on GoFundMe. We will also be funding costs from friends and family.

III. Technical Concept Report

a. Technical Summary

Over a billion birds die each year due to collisions with human obstacles, such as windows and communication towers. Windows kill over 900 million birds annually, while tower kill puts 52 bird species on the Bird of Management Concern List. Already, ⅓ of all North American bird species require urgent conservation action.
We have developed an innovative system called VFLY which will use bird species specific predator sounds to help birds avoid hitting window glass in buildings. VFLY uses a motion sensor, camera, artificial intelligence visual recognition software, and speaker. Once a bird comes within the vicinity of a window or tower, the motion sensor will detect motion, and the camera will capture an image. This image will be analyzed by visual recognition software for species identification. Once the species have been identified, the device will play a specific predator call, scaring the bird away. Compared to other sound alarms, VFLY plays species specific predator sounds, ensuring that birds do not adapt to these sounds.

For developing our VFLY system, we decided to chose commercially available hardware platform components and software to keep the cost low. We chose a Raspberry PI model (with BCM2836 Application Processor and SOC Raspberry Pi 2 B Board 900MHz CPU 1GB RAM Linux/Win 10 OS) as a hardware platform which costs around 30$s. For our capturing the pictures, we used the standard Raspberry Pi Camera V2 which comes with the Raspberry Pi 2 Model B edition 9 and costs around 10$.

For visual recognition, we selected IBM Watson API available via the Internet. We developed our software using Python 2.7, and used Apache web servers to run the VFLY app.
We created a database containing species/predator relationship, and collection of predator sound files, and used these files to generate sound on the VFLY.

To validate the functionality of VFLY, we executed a three-phase plan involving our Raspberry PI prototype and Watson API. Our three phases included computer testing, lab testing, and field testing.

b. Need Statement:

Bird collisions with human obstacles, such as windows and communication towers kill over one BILLION birds a year, over 10% of the total bird population. While window kill is the leading cause of bird fatalities (900 million birds annually), tower kill is also concerning, as 52 of the 200 bird species impacted are already on the US Fish and Wildlife Services' Bird of Management Concern List.

As humans continue to build houses and infrastructure, this problem will get worse. Since 2000, communication towers sites has increased by 250% (Figure 13). Already, ⅓ of all North-American bird species need urgent conservation action.

Figure 13. U.S. wireless towers and sites, 1984-2025

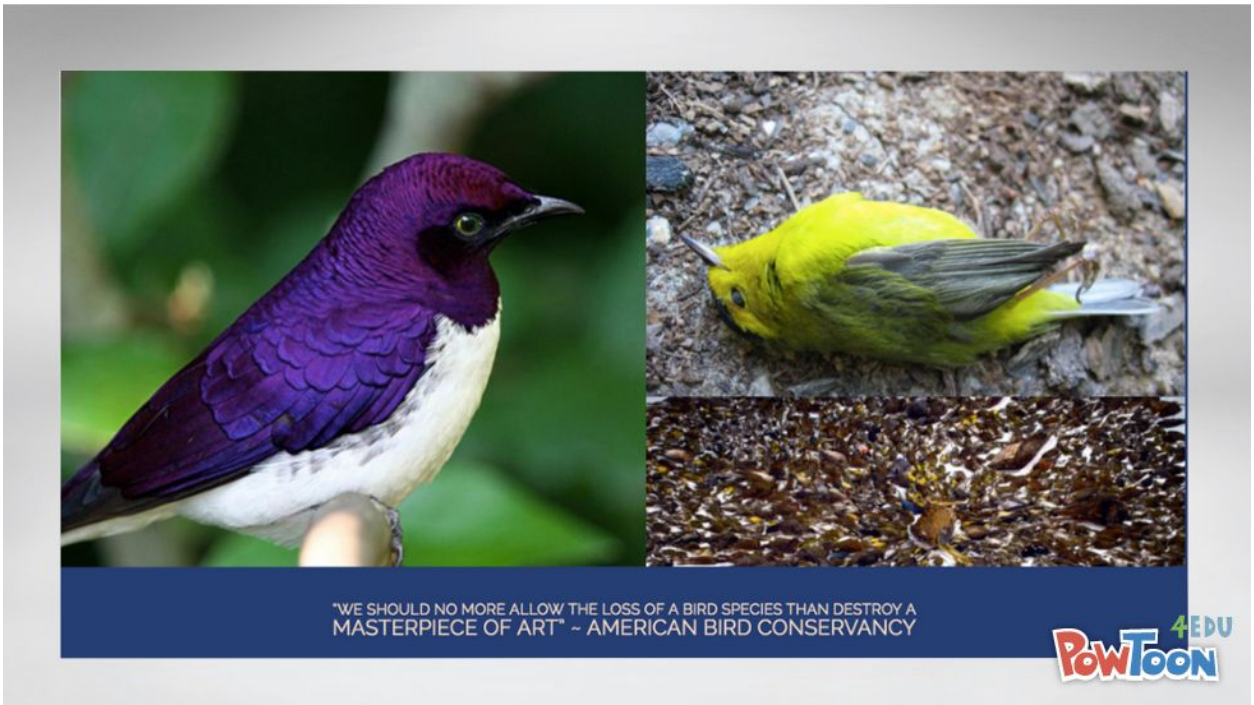
Why do birds crash into windows and towers? Instead of seeing the glass, birds see the reflection of the outside nature, and crash into windows. At night, many migratory species hit towers, because they are lured towards the deceptible safety of the lights on the towers.

Why do birds matter? Birds are a vital part of our ecosystem and provide invaluable beneficial services. Listed below are the important functions of birds in our world.

1. **Agricultural Help**: Insectivorous birds prevent the spread of pests in crops, pollinator birds help flowers, birds also slow the spread of disease by consuming carcasses. These services have been valued at over $5000 per square mile.
2. **Indicators of Environmental Change:**
    a. **Signal Habitat Quality**: Bird declines alert humans to environmental problems before significant damage is done (i.e. in the Everglades, the construction of canals and levees reduced the prey availability, which resulted in mass decline of the population of wading birds).
    b. **Signal Pollution:** Birds were among the first group of animals that declined as a result of the use of DDT.

c. **Signal Disease Outbreaks:** A prominent example would be the outbreak of the West Nile Virus. Through examining bird carcesses, scientists were able to predict the disease earlier
d. **Psychological Aesthetic:** The US Fish & Wildlife Service reports that 47 million people are registered birdwatchers. As awareness of this huge problem increases, many people want to help the majestic birds, like us (Figure 14).

Figure 14. Aesthetic and Beautiful Value of Birds



An existing means of preventing birds from colliding into glass windows is the use of sound alarms. However, studies have shown these devices to be ineffective. Sound alarms could be using ultrasonic frequencies so the sounds are not noticeable to humans. However, most birds have a hearing frequency range similar to humans, rendering these alarms useless.
Other sound alarms may be playing loud sounds at regular intervals. Researchers have determined that the birds eventually adapt to these sounds, and do not react to them.
VFLY will be able to play species specific predator sounds, making the sounds biologically relevant to birds, and causing them to react by changing their flight path. Also, since these are naturally occurring sounds, birds will not get used to them.

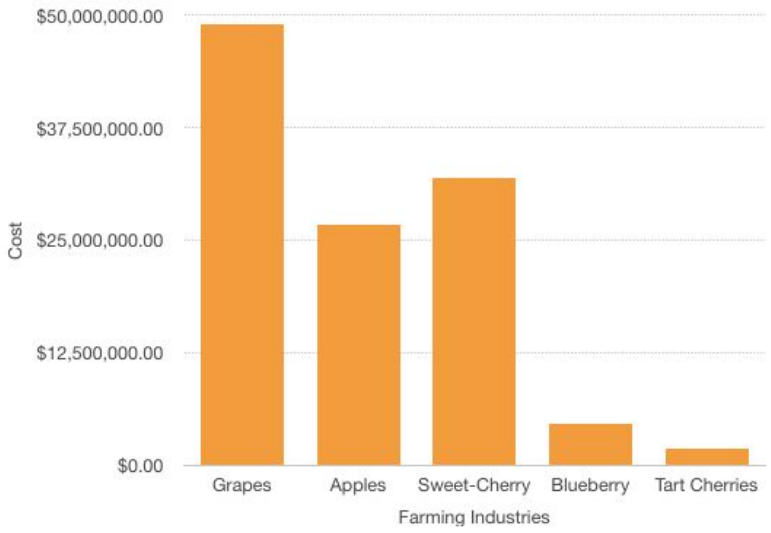
Another existing option is to add decals to glass windows at houses or skyscrapers. This would make the windows visible to the birds. However, this has a high cost to retrofit decals on existing structures. For example, after observing high number of bird deaths, the Viking Stadium estimated a cost of $60 million to install bird-safe glass (*https://www.cbssports.com/nfl/news/replacement-glass-on-new-vikings-stadium-could-cost-60-*

million-extra). VFLY is a compact device that can be installed on each side of a building (one device for every 2 floors). This would make VFLY an inexpensive solution to this problem.

Legislature in multiple cities has been passed which require for bird-friendly measures in all buildings. Leadership in Energy and Environmental Design Certification (LEED), which is the most widely used green building rating system in the world have recently introduced a bird collision deterrence pilot certification program. VFLY can provide an inexpensive option for builders to comply with the legislatures and certifications.

Apart from saving the declining bird populations, VFLY can be used in these areas -
1. **Farmers:** The majority of birds aid farmers by eating out the bugs/pests in crops. Birds can destroy up to 98% of overwintering codling moth larvae, a major pest of apples -- increasing apple production by 66%. Birds also reduce insect pests in conventional alfalfa by over 33%. However, some birds actually eat the crops, which results in financial losses and less growth (Figure 15).
Hence, farmers need to selectively allow certain bird species in their fields, and scare away other bird species.

Figure 15. Costs of Pest Birds in Farming Industries



There aren't any effective solutions. Putting a net over crops would cost $400 an acre, which could set a large farmer back more than $400,000. Scarecrows scare away all bird species, including the ones that benefit the farmers.
VFLY can be programmed to scare certain species (that destroy crops). The use of species identification allows us to change VFLY according to our needs. Our device would be much cheaper than netting and would scare away the "bad" bird species, while still letting the "good" species.
2. Pest Control:

Birds occupying balconies, sidewalks, homes, and warehouses pose a serious health and economic threat. Pigeons can transmit 60 different diseases alone. The cost for clean up

and bird proofing houses and balconies is $1000. Additionally, the cost of cleaning 500 ft of sidewalk is $3,500 annually! Companies pay thousands of dollars to keep birds out of their warehouses.

VFLY could be used to scare these birds away, saving thousands of dollars annually to cities, homeowners, and companies. Additionally, the health hazards will be prevented, saving more lives and money.

3. Data Collection/Birding App: VFLY will store all data, including pictures, locations, and image recognition results, which can be used by scientists to study bird migration patterns and population trends.

VFLY can also serve as a birding app. Other available bird apps rely on users to report rare bird sighting in their vicinity, VFLYs can be used to automatically notify registered users on rare bird sightings.

c. Background Technology:

VFLY is build on two major existing technologies - a computer board and visual recognition software.

To identify specific bird species, we had to evaluate several different existing visual recognition softwares against carefully chosen criteria . We first conducted research and found the available visual recognition softwares online. After identifying several, including IBM Watson, Clarify, Microsoft, and Google, we distinguished different criteria (below) to evaluate these softwares.

Familiarity: We judged each recognition software based upon on our familiarity, experience, and knowledge of the system. Overall, we had low familiarity with all of them, except IBM Watson API.

Accuracy: It's important for the visual recognition software to be accurate, so VFLY can play the correct predator sounds to scare the specific bird species away. We tested for accuracy by supplying each visual recognition software the same ten pictures of different bird species and recording results. We assigned values of high, medium, and low for each software and found that IBM Watson and Cloudsight had relatively high accuracy.

Cost (per 1000 images): When manufacturing a device or product, cost is always an important factor to consider. Using the internet, we were able to find the costs for each software and compare them.

Latency: We understand that our device will have to identify the bird species as quickly as possible after the image has been captured to let the bird have enough leeway to escape. Therefore, we tested for latency by supplying each recognition software the same ten pictures and record the response time taken.

Custom Training: Custom training is an extremely important criteria. The visual recognition softwares won't be equipped to identify all bird species and therefore, we need the ability to "train" the models to identify more native bird species that were

previously unrecognized. Our research shows that only the IBM Watson API and Clarifai had the feature for custom training.

Access to Experts: As we continue to develop our product, we will need to work with experts working on these recognition softwares. We already had access with IBM Watson experts and worked/consulted with Dr. Matt Hill and Dr. Ruchir Puri, chief architects of IBM Watson.

Overall, based upon our analysis, we found that IBM Watson was the best fit due to its custom training ability, relatively low cost, superior accuracy, quick response time, high familiarity, and access to experts (Figure 16)

Figure 16. Comparison of Visual Recognition Softwares

	IBM Watson	CloudSight™	clarifai	Microsoft	Google
Familiarity	High	Low	Low	Low	Low
Accuracy	High	High	Medium	Medium	Medium
Cost (per 1000 images)	$2.00	$4.00	$1.20	$1.50	$1.50
Latency	2 seconds	11 seconds	1.5 seconds	2.5 seconds	2.5 seconds
Custom Training	✅	❌	✅	❌	❌
Confidence	0.97	❌	0.84	❌	0.94
Access To Experts	✅	❌	❌	❌	❌

The **IBM Watson Visual Recognition** service uses deep learning algorithms to analyze images for scenes, objects, faces, and other content. The response includes keywords that provide information about the content. A set of built-in models provides highly accurate results without training. The service provides ability to create custom models by labeling positive and negative images. The built-in models for IBM Watson are successful in including bird species as classifiers when analyzing bird images.

We conducted similar intense analysis on the different microprocessors available on the market. We wanted to find the best fit microprocessor (hardware system) for our prototype. We evaluated various hardware systems, including the Raspberry Pi, Banana Pi, Omega, and the Orange Pi, against the following criteria…

Cost: Again, when manufacturing and creating a device such as VFLY, cost is important to determine. Using internet resources, we found the costs for each of the different hardware systems we were comparing.

Portability: Our device has to be extremely compact, so VFLY wouldn't interfere with the look of a building or house. Additionally, VFLY has to be easily transportable for commercial retail purposes. We calculated dimensions and assessed portability accordingly.

Camera/Motion Sensor/Speaker Attachment: These are important components of VFLY, so we had to make sure each microprocessor had portst that allowed the camera, motion sensor, and speaker to be attached.

WiFi: Initially, our prototype is supposed to connect to the WiFi and therefore, we evaluated the hardware for it. However, as we develop our product, we will put the IBM Watson model on the hardware to minimize latency and eliminate the need to connect to WiFi.

Memory: We will be running our software programming on the device, which requires memory. We determined that we wouldn't need more than 1 GB, and through online information, we were able to assess each hardware system to see if it met the requirement.

Familiarity: Like the visual recognition softwares, we wanted to work with a device that we had experience and knowledge about. We assigned high familiarity to the Raspberry Pi because all of our teammates had worked on projects involving the Raspberry Pi before.

Overall, based upon our analysis, we found that the Raspberry Pi was the best fit due to portability, relatively low cost, WiFi, camera/speaker/motion sensor attachment ability, and high familiarity (Figure 17).

Figure 17. Comparison of Microprocessors (Hardware System)

Computer	Raspberry PI	Banana PI	ODRIOD-C2	NanoPI 2 Fire	VoCore2	Omega2	Orange PI-PC2
Cost	$35.00	$70.00	$40.00	$23.00	$12.00	$5.00	$20.00
Portability	✅	✅	✅	✅	✅	✅	✅
Programming	Python	Python	Python	Python	Python	Python	Python
Camera	✅	✅	✅	✅	✅	❌	✅
Motion Sensor	✅	✅	❌	❌	✅	❌	✅
Speaker	✅	✅	✅	✅	✅	✅	✅
WIFI	✅	✅	✅	❌	✅	✅	✅
Memory	1 GB ✅	2 GB ✅	2 GB ✅	1 GB ✅	128 MB	64 MB	1 GB ✅
Familiarity	High	Low	Low	Low	Low	Low	Low

The Raspberry PI is a single board computer that can be used to build a compact device with hardware components such as motion sensors, cameras and speakers. It can be powered by a commercially available battery pack.

d. Concept Details:

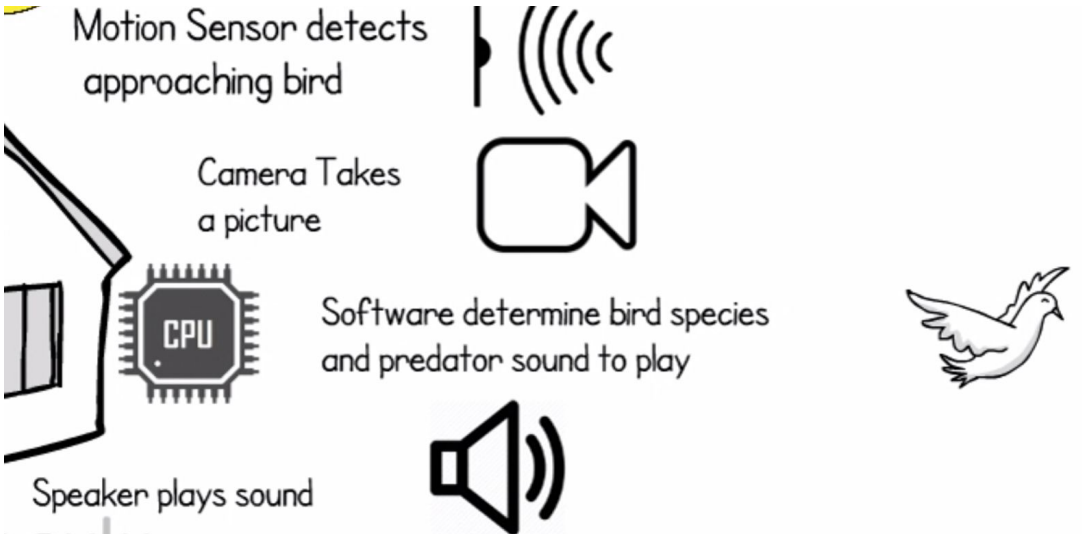


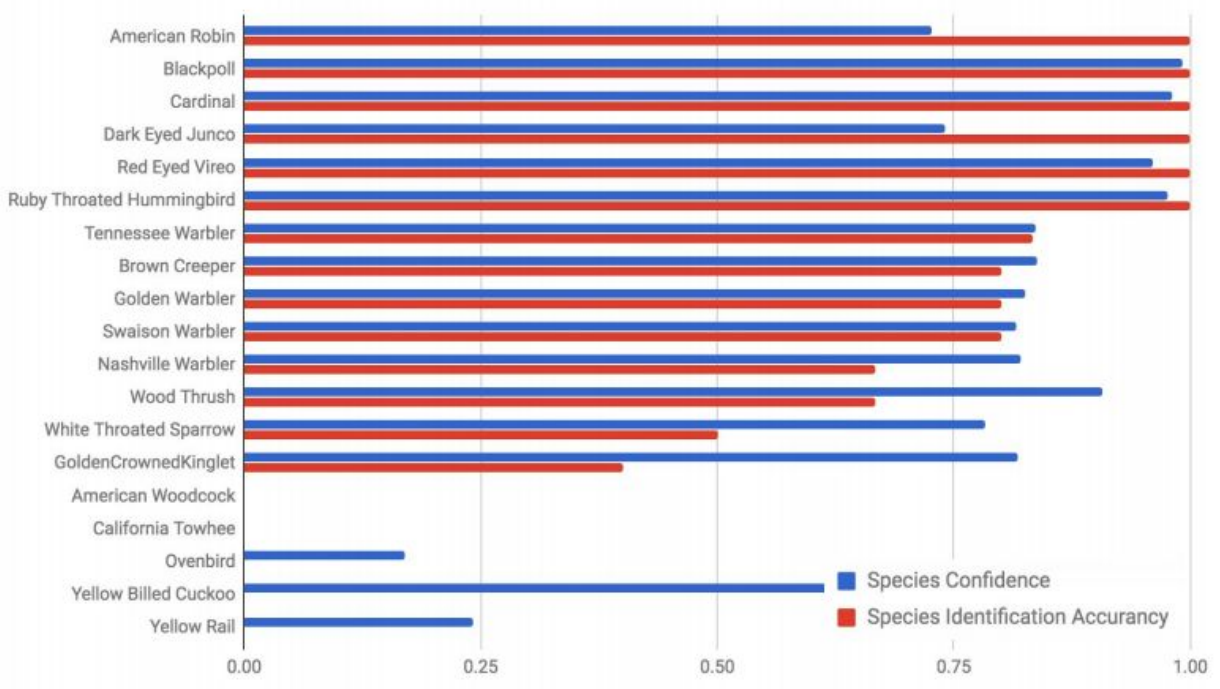
Figure 18. VFLY Conceived Functionality

To assess the feasibility and the function of VFLY, we executed a three phased plan.

Visual Recognition Programming and Testing:

We identified bird species that had been heavily impacted by window or tower collisions. After identifying around 20 bird species, we gathered multiple images of each species from the Internet. We ended up with more than 100 images. Using IBM Watson Python API, we wrote a program that would give us the "summary classification" for each image. The summary classifications consisted of the Watson confidence level of the animal and bird species present in the image.We used various resources and tutorials available on the IBM Watson website to create our program. Our results demonstrated that IBM Watson was highly accurate, reaching high confidence with accuracy for 18 of the bird species (Figure 19).

Figure 19. IBM Watson Bird Species Identification Accuracy/Confidence Levels



To increase the species coverages, we downloaded ~6,000 images from the **Caltech-UCSD Birds-200-2011 Dataset**, and re-ran our test program. Out of the total 250 bird species tested, Watson was able to identify the vast majority.

However, we realized that the IBM Watson API wouldn't be able to recognize all native bird species. As a result, we enlisted the help of experts, such as Dr. Matt Hill (visual recognition architect at IBM), and used their inputs to "train" the Watson model. By supplying Watson zip files of Negative and Positive Images, we were able to create a new classifier for the specific bird species we were trying to Watson to detect. As a result, IBM Watson would be able to identify that species it couldn't before. For example, we were able to train Watson to recognize the Yellow Rail and California Towhee bird species with 100% accuracy and 80% confidence (Figure 20)! By successfully conducting model training, we were able to prove that we can identify all native bird species by continuing to Watson model train.

Figure 20. WATSON Species Identification Increased With Custom Model Training

Before WATSON Custom Modeling

	Species Identified	Species Confidence
CaliforniaTowhee	Solitaire	0.45
CaliforniaTowhee	Sparrow	0.39
CaliforniaTowhee	Wren-tit	0.6
YellowRail		0
YellowRail		0
YellowRail	Snow Bunting	0.24

After WATSON Custom Modeling

	Species Identified	Species Confidence
CaliforniaTowhee	California Towhee	0.69
CaliforniaTowhee	California Towhee	0.73
CaliforniaTowhee	California Towhee	0.75
YellowRail	Yellow Rail	0.88
YellowRail	Yellow Rail	0.79
YellowRail	Yellow Rail	0.86

Prototype Development and Lab Testing: After determining the high accuracy of Watson API, we wanted to build and validate a standalone portable device that can capture images of birds, identify the species, and play predator sounds accordingly. For our prototype, we chose commercially available products to keep costs low. We bought all of the required parts (motion sensor, camera, speaker, and battery pack) from various online retailers and bought several Raspberry Pis from the online Raspberry Pi shop. Working with tutorials online, we took small steps and tested our parts. For example, firstly, we attached the camera to the Raspberry Pi via wires and wrote a simple program to capture an image and display it on the screen of the Raspberry Pi. As a result, with every step, we were ensuring that our device was working properly. Once the entire prototype was built, we put our device inside a cardboard case (for casing) (Figure 21)

Figure 21. Initial VFLY Prototype

Before writing our program, we created a logic flowchart, which explained the steps our program would take depending on the previous actions (Figure 22). We wrote our Python program, which programmed all the parts of VFLY (Figure 23)

Figure 22. VFLY Programming Flowchart

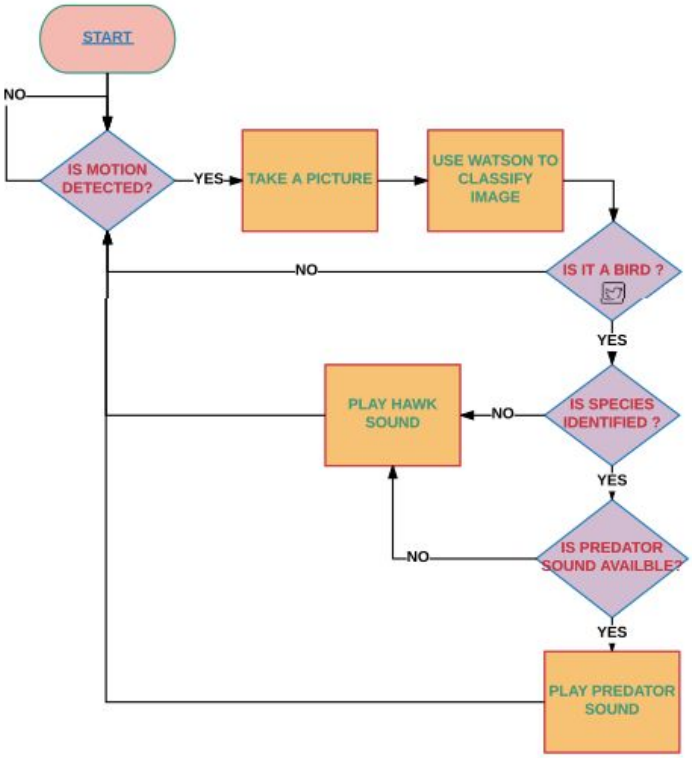


Figure 23. VFLY Python Programming

complete.py

~/Downloads/complete.py

```
1  from gpiozero import MotionSensor
2  from picamera import PiCamera
3  from time import sleep
4
5  from watson import getSummaryClassification
6  import sound
7
8  pir = MotionSensor(4)
9  counter = 0
10 motion_detected = 0
11 while True:
12     if pir.motion_detected:
13         if motion_detected == 0:
14             counter=counter+1
15             motion_detected = 1
16             print("Motion detected!" + str(counter))
17             print('Starting Camera')
18             camera=PiCamera()
19             camera.start_preview()
20             sleep(1)
21             print('Capturing image');
22             camera.capture('/home/pi/Desktop/image.jpg')
23                         print('picture done')
24                         myresult = getSummaryClassification('/home/pi/Desktop/image.jpg')
25             if 'bird' in myresult:
26                 print('bird....')
27                 sound.play('./Sounds/Hawk.wav')
28             print('Stopping preview and exiting')
29             camera.stop_preview()
30             camera.close()
31             sleep(1)
32     else:
33         if motion_detected == 1:
34             motion_detected = 0
35             print("Still.......")
36
37
```

Now, we were ready to test our device. Before actually testing with real birds, we printed our pictures of birds and stuck them onto cardboard. We would place them in front of our device to test for the camera, motion sensor, and speaker functionality. To make our testing more realistic, we used realistic stuffed bird models and tested VFLY with them. Overall, all of our results were heavily monitored and recorded. We found that all the parts of VFLY were operating smoothly

Field Testing: We wanted to test VFLY with real birds. All of our team members placed VFLYs in their backyards. We put birdseed in front of our devices to attract birds (Figure 24). We were delighted that our device took hundreds of pictures and identified of local bird species, such as

Figure 24. VFLY Field Setup

Figure 25. Pictures from Field Testing

the Dark-eyed Junco (Figure 25). All of these pictures and results are carefully recorded in our testing binder. Next, we met with our local and NYC Audubon societies and demonstrated our product, VFLY, to them. We were granted permission by our local Audubon society to test VFLY at their bird feeder locations. Based upon their feedback, we created a testing set up in various locations and placed VFLY systematically in front of the bird feeders. Our device captured hundreds of images, identified them, and played predator sounds. All these pictures and classifications are also documented. Throughout our field testing journey, we were constantly upgrading and enhancing our prototype (Figure 26). For example, we realized that our device would need to work in any weather conditions so we had to weatherproof VFLY. We designed a hard case on a 3D design software and used our local libraries 3D printer to manufacture our enclosure. We found that our enclosure made VFLY more durable, strong, and suitable for all weather.

Figure 26. Progression and Evolution of VFLY Prototypes

We also found that our motion sensor was extremely sensitive and the environmental factors (such as the wind or trees swaying) were triggering it. We quickly adjusted by reducing the opening in our enclosure for the motion sensor, which made it less sensitive. While we already conducted extensive field testing, we still have to organize further testing with various different variables (see more below).

While testing and developing our technology, we considered many factors and laid out performance specifications:

Watson Latency Requirements: Latency is an important factor, as VFLY needs to play the relevant predator sound as soon as it detects an approaching bird. Based on our analysis of typical window sizes, average bird flying speeds, angles at which birds divert on hearing predator sounds, Watson would have to provide species classifications within 1/6th of a sec. Putting our individual Watson model on the hardware system would greatly reduce our latency time. We verified with IBM Watson experts that our goal of 1/6th is feasible. To actually accomplish this, we were will be working with Dr. Ruchir Purl, a premium Watson Architect, and using resources that IBM Watson has provided.

Camera Specifications (Blurriness, Distance, Image Resolution): Based upon our calculations, the camera will have to take an image from 15 - 20 feet away. On VFLY, cameras will have 20 X 20 peripheral vision, which means that building and tower towers will need to place one VFLY in every direction every 20 feet. However, we have considered many factors such as blurring of the image capture. According to IBM Watson experts, low resolution pictures can actually increase the response time of Watson. We will be conducted more tests using different camera models, different distances, different lighting conditions, etc.

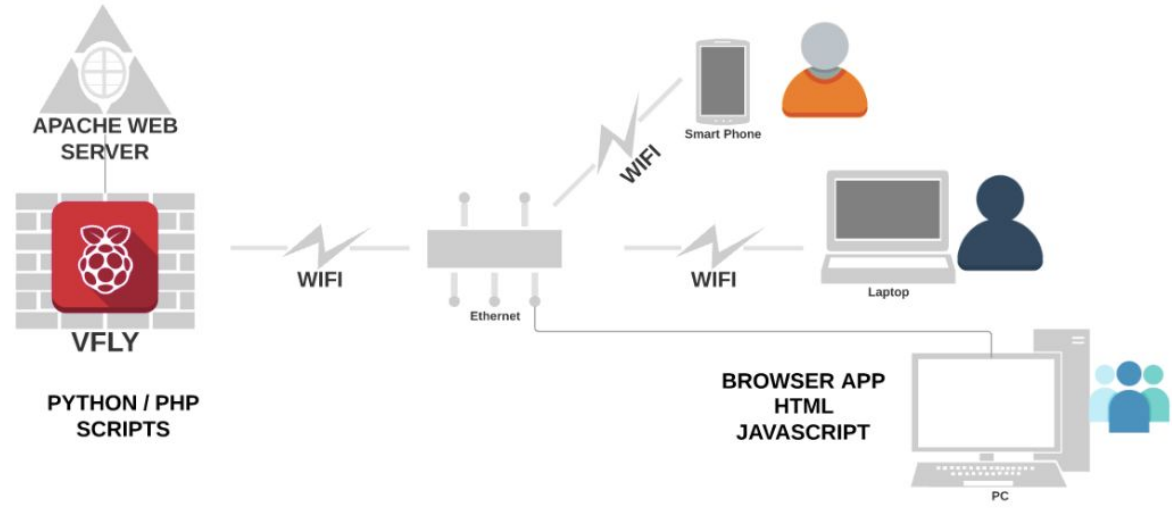
Lighting Condition: Since birds still hit windows and towers in the nighttime, our device will have to take pictures in the dark. We propose the use of a night vision camera. Again, we will conducted further studies on the accuracy and resolution of these cameras. Additionally, we thought of record bird calls in the night and using their sounds to identify specific species. When we met with the Audubon Society, they validated our idea and stated that each species has a specific birding call. We will experiment with sound recognition softwares and conduct intense testing on them, just like we did on Watson API.

Watson Unable to Identify: If Watson is unable to identify a picture in the field, we will resort to the region default behavior. For every region, we will determine the most prevalent predator of the most bird species. Therefore, if Watson is unable to recognize a bird, the most common predator sound will be played, still ensuring our effectiveness.

Weather-Proof: Our device has to function in all weather conditions. Therefore, we design a sturdy 3D case on Solidworks and used our local library to produce it. During our field testing in the extreme weather, our enclosure protected VFLY and still ensured its functionality. However, we still have to test multiple other enclosure designs to determine the best fit for VFLY.

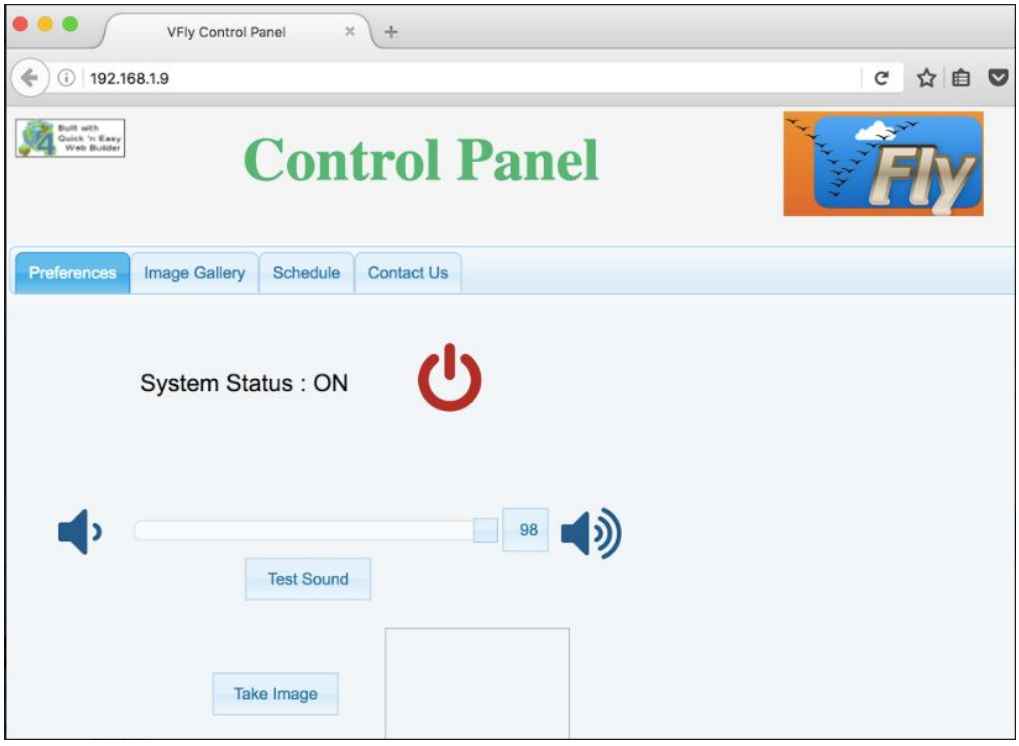
User Comfort: As we mentioned before, our users are very important to us. We will be providing all of our users with a simple app. This app was built on the Apache Web Server and current connects to VFLY via its IP Address (Figure 27).

Figure 27. Network Representation for VFLY User Configuration Application



The app has settings for volume, on/off buttons, time schedules (Figure 28).

Figure 28. VFLY User Settings



We have added innovate features as well, such as an image gallery and automatic notifications for local rare bird species sightings (functions as a birding app for bird enthusiasts).

Loudness: According to professional ornithologists, the bird hearing range is roughly the same as humans (between 1kHz and 4kHz). However, we understand that we will have to play

the predator sounds at different volumes depending on the distance of the bird. We constructed an algorithm which calculates the volume (in decibels) the speaker will have to play depending on the bird's distance from the device (measured from the camera).

Further Work/Proposed Development: Our next steps and further testing are detailed in our Product Roadmap (Figure 29).

Figure 29. VFLY Product Roadmap

Hardware: To design our prototype, we chose commercially available speakers, motion sensors, and cameras that were readily accessible. However, we identified various different models and designs for these components. We will be using our funds to order these parts and conduct rigorous testing, determining distances the camera can take, motion sensor sensitivity, and speaker volume adjustment, to find the best fit products for VFLY based upon specific performance specifications detailed above.

Once we determined the specific external components of VFLY, we will be designing a Printed Circuit Board (PCB). The PCB will allow for VFLY to be even cheaper and compact as we will be removing all the excess parts of the Raspberry Pi VFLY doesn't need for its functionality. We will be crafting our PCB with digital drawing softwares with the aid of companies, such as Predictive Designs. Our thorough PCB will contain dimensions, circuits, ports, and other design elements.

After completing a PCB, we will be manufacturing prototypes for testing using the Raspberry Pi Customization Service.

Next, since VFLY is an electronic device, we will have to get specific certifications (ex. FCC, RoHS, and CE) from the government before bulk manufacturing. We will be working with government officials and conducting more testing to prove our device deserves these certifications.

Then, we will start bulk production using the Raspberry Pi Customization Service, which offers cheap product manufacturing.

Software: We have already demonstrated successful Watson model training and will continue to train Watson as we test VFLY with new species. As a result, VFLY will be extremely comprehensive and would be able to identify almost all species.

We require the Watson latency to be ⅛ of a second (based upon various calculations). Dr. Ruchir Puri demonstrated great interest in our product and will be mentoring us on how to accomplish this.

We need to set up numerous field tests with bird feed at various distances (from 2 feet - 15 feet) from the VFLY device to determine impact of Watson API accuracy with distance.

We will continue to develop our user app, adding more features such as automatic software updates and bird “dictionary” with pictures of exotic birds for bird lovers to enjoy.

We already have created an initial predator-sound database with over 20 bird species and their predator sounds. As we continue to develop VFLY, we will add more species to expand the global range of VFLY. Additionally, we developed a program (for bird species that have multiple predators) that will randomize the predator sound playing to scare that specific bird species. Since predators and prey are part of the natural ecosystem, birds will never get accustomed to hearing predator sounds.

V. Product Video: https://www.youtube.com/watch?v=XjEL8MQfOT8