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Feasibility of Webcam Implementation in Acadia National Park

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Abstract

Acadia National Park, one of the smallest national parks geographically, is visited by millions of people each summer. In response to the significantly increased visitor volume, the National Park Service (NPS) and the Friends of Acadia, a non-profit conservation organization, have been experimenting with several methods in an attempt to reduce traffic congestion. One promising approach is to establish a webcam monitoring system to allow for real-time traffic updates in the most visited areas in the park. To examine this approach, our team implemented a proof-of-concept webcam system to monitor visitor traffic in some of the park's most congested areas. This report includes an evaluation of the performance of the associated webcam network.

Acknowledgements

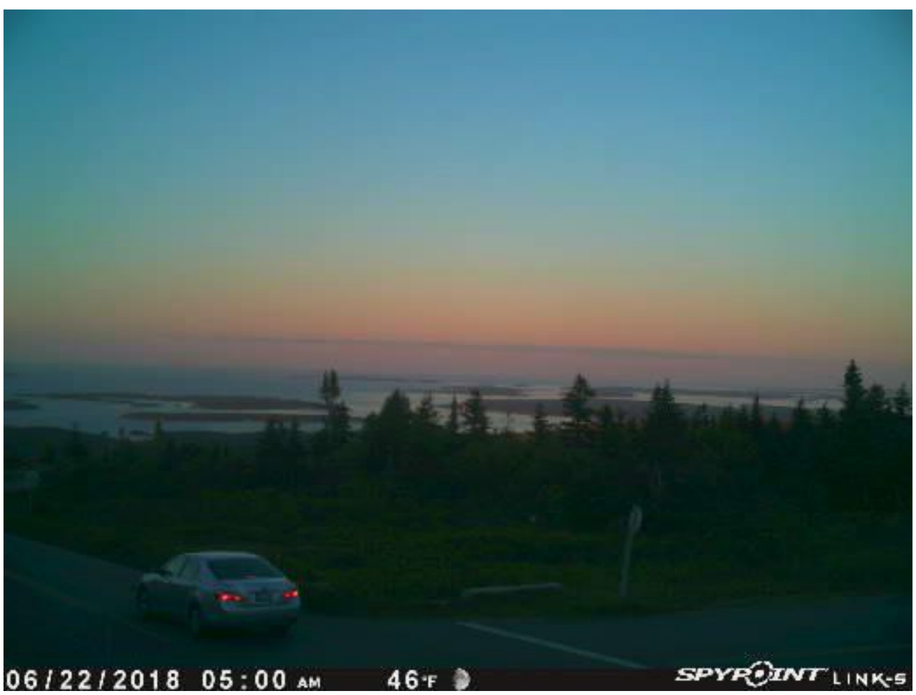
Our team would like to thank several of the Acadia National Park rangers who helped us with our project. Specifically, Ranger John Kelly along with our sponsor and science coordinator, Abe Miller-Rushing. These rangers helped us along the way by providing feedback about our camera locations and ways we can improve. We would like to thank the lead recreation technician from Friends of Acadia, Rebecca Flesh, for the same reasons. We would also like to thank the 2018 Cellular Connectivity team for answering our questions regarding cellular connectivity and sharing their findings with us. We want to thank Paula Quinn, our ID 2050 instructor, for helping us work through our initial struggles with the project. Lastly, we would like to thank our project advisor, Professor Bianchi, for guiding us in all aspects of our project.

Executive Summary

The overall goal of our project was to test the feasibility of webcams within Acadia National Park to aid in traffic monitoring of congested areas of the park. Our team sought to achieve this goal through the following four objectives.

> Objective 1: Identify the Most Congested Areas in the Park
> Objective 2: Purchase and Setup Webcams to Monitor Traffic Condition
> Objective 3: Share the Recorded Images with Park Officials
> Objective 4: Evaluate the Feasibility of a Webcam Network

Our team chose to test the camera at Cadillac Mountain, Jordan Pond, Bubbles, Sand Beach, Thunder Hole, Otter Cliff, Otter Point, Acadia Mountain, Beech Mountain, Echo Lake, Bass Harbor Head Lighthouse, Mill Field, Gilley Field and Hulls Cove Visitor Center, fourteen locations in total. We chose these locations based on recommendations from park officials and research we conducted to identify places where webcams would be most useful.



Example Spypoint Image on Cadillac Mountain

We then researched webcams that had the ability to transmit images wirelessly through cellular connectivity and contained its own power source, such as solar panels. We decided on the Spypoint Link-S, which met both requirements. The camera had a small solar panel on the top of the camera that helped to keep the batteries charged. Additionally, the camera came with its own cloud server where images taken by the webcam would be transmitted and stored. The cloud server was accessible to anyone with the username and password on both desktop and mobile app platforms. This allowed anyone with cell signal to access the images in real-time. Since cell signal was necessary for the webcam to transmit images to the cloud server, we purchased a cell boosting antenna in an attempt to transmit images in areas with reportedly little to no signal. We then spent several weeks testing the camera in the locations mentioned, assessing whether there was enough cell signal to transmit the images to the cloud server. The feasibility of the webcam system was determined through the camera's signal strength and ability to upload pictures along with other aspects, such as battery life and picture quality.

Our setup involved the use of a twelve-foot, extendable painting pole. Our camera was mounted about six feet up the poll and the cell boosting antenna was attached at the top. Over the course of five weeks, we tested the camera with both the signal boosting antenna and regular short-range antenna at all fourteen locations.

We started our project by testing the camera on Cadillac Mountain for a week and a half to test how the camera would hold up if implemented long term. We learned that the quality of the images significantly decreased when the camera lens became wet, whether by condensation or precipitation. This was especially true when the camera was taking infrared pictures, as the water reflected the infrared light back at the camera. However, when the weather is unideal, traffic congestion is expected to be less of an issue.

Battery life was another issue we ran into when leaving the camera out on Cadillac Mountain. Since the camera was taking and uploading pictures every three minutes for eighteen hours a day, the battery drained quickly. During a period of four overcast days, the battery drained from 83% to 40%. In order to remedy this issue, we explored additional accessories from Spypoint that can help extend battery life, such as a lithium battery pack or a 12-Volt battery.

After testing on Cadillac Mountain, we moved the camera to the other thirteen locations. This time, we only had the camera at each subsequent location for a half hour to an hour. We set up the camera with the range boosting antenna on the pole and allowed the camera to take a few pictures before moving on. The data regarding cell signal at each of these locations was later analyzed to help determine feasibility. With the cell boosting antenna, our team was able to successfully transmit images in real-time at all fourteen locations tested.

Our Setup with the Cell Boosting Antenna

Based on our experience with the Spypoint Link-S, we recommended a more robust set up for long-term usage: the Spypoint Link-Evo camera, along with a 12-Volt solar panel, 12-Volt external battery, range boosting antenna, and a few other various accessories. We believe that future teams should explore the use of the Raspberry Pi camera, a programmable webcam that could allow the park to use file transport protocol (FTP). FTP enables the park to upload the images and make them viewable to the public. Our team showed that it is possible to transmit images throughout much of the park, so the next step would be to make these images accessible to as many people as possible.

Authorship

Matthew Bruno - Contributed to the Acknowledgements, Introduction, Background, Methodology, Conclusion, Appendix A, and the Presentation. Specifically, he worked on the first paragraph on the Introduction, "Webcams as a Solution" and editing the project objectives. Matthew also created all the graphics found in the Background, Methodology and Results. Additionally, he was responsible for troubleshooting issues with the Spypoint camera.

Mary Cromwick - Contributed to the Executive Summary, Introduction, Background, Methodology, Discussion and the Presentation. Specifically, she worked on the first paragraph of the Introduction, "Traffic Congestion and Nature Concerns", "Cellular Connectivity", the tables and explanations in the Discussion, and editing the Introduction and the Background. Additionally, she was responsible for proofreading the paper as a whole, checking for consistency and grammar.

Yusheng Feng - Contributed to the Abstract, the Introduction, Methodology, Background, Conclusion and Recommendations, the References, and the Presentation. Specifically, he worked on the third paragraph of the Introduction, "Project Overview", "Cost of webcams", "Ethics of Webcams", and the Recommendations. Yusheng was responsible for exploring the Raspberry Pi camera. He formatted the final document and assisted in proofreading the paper as a whole.

Sections of the paper that were not explicitly stated above
were worked on equally by all members of the group.

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1.0 Introduction

Visitation to national parks has been on the rise for years. Acadia National Park has seen the number of visitors increase from 2.25 million visitors a year in 2013 to 3.51 million in 2017 (National Park Service, "Statistica," 2017). Severe overcrowding often results in rangers closing roads that lead to popular spots, such as Cadillac Mountain, due to the limited parking spots and space for visitors. In the summer of 2016, Cadillac Summit Road was closed twelve times (Broom, 2017). From June 28 to September 4, 2017 the road was temporarily closed forty-nine times (Acadia National Park on my Mind, 2017). While overcrowding has become a regular occurrence, there has not been any significant change in the procedure for closing roads. Currently, park rangers or ridgerunners must monitor visitor congestion on site and determine if the congestion poses a safety threat, resulting in a temporary road closure (Kelly, 2018). This process is not only inefficient, but also frustrating for visitors. Visitors might experience temporary road closures without any prior notice, possibly preventing them from seeing popular tourist destinations.

In order to improve the process described above, Acadia National Park has been looking into ways to better monitor visitor traffic. One proposed solution is to use webcams, which have the benefit of allowing the park to monitor visitor traffic without the need to increase personnel. Several national parks already have webcams in use. For example, Yellowstone park uses webcams to monitor traffic at park entrances. Acadia also has a few webcams installed throughout the park, but these only monitor weather patterns. One of the major obstacles in using webcams to monitor park traffic is that many of the most congested areas don't have wireless connectivity or power sources. We looked to solve these issues by using the Spypoint Link-S camera (Spypoint Link-S). This camera uses cellular connectivity to upload the images captured to a cloud server and comes with a solar panel to charge the rechargeable batteries.

The goal of our project was to determine the feasibility of webcam usage to monitor traffic in congested areas of the park. The park wished to experiment with a webcam network that allowed for real-time monitoring by rangers and eventually visitors. To achieve this goal, we identified fourteen of the most congested areas in the park, including Cadillac Mountain, Jordan Pond and Sand Beach, to implement and test our system (Manning, 2009). We came to the decision to use the Spypoint Link-S after comparing several other webcam systems and streaming options. A demo network was established by installing and testing the Spypoint webcam at the locations identified. The feasibility of the camera system was determined by studying the camera's performance in the field.

2.0 Background

2.1 Traffic Congestion and Nature Concerns

The number of visitors to Acadia National Park has increased steadily over the last five years. In 2013 the number of visitors was 2.25 million. That number jumped to 3.51 million in 2017, nearly a 56 percent increase (National Park Service, “Statistica,” 2017). While most national parks have seen an increase in visitors, such an increase is especially problematic for Acadia. Acadia receives a disproportionate number of visitors compared to its size. Acadia is one of the five smallest national parks, yet it ranks in the top ten most visited national parks (National Park Service, “IRMA Portal,” 2017). High visitor volume has several negative consequences, affecting both the park and visitors themselves.

Studies have shown that a large number of visitors can result in damaging effects on the park ecosystem. High visitor volume tends to disturb plant life, especially when visitors stray from trails. When the plants have a chance to regrow, only the most resilient species can survive the harsh environment. This phenomenon results in a decrease of diversity with respect to species found within the area, as many of the more delicate species can no longer survive. It is also speculated that straying from trails disturbs the soil, further eroding trails (Manning, 2009).

An increase in the number of visitors also takes away from the visitor experience. Professor Roger Manning has done extensive research over the last couple of decades looking at visitor experience in national parks. He uses Visitor Experience and Resource Protection (VERP) as a standard to determine the maximum number of people that can be within an area of a park, all without visitors perceiving it as overcrowded (Manning, 2001). One VERP study found that the maximum number was fourteen people, but many visitors preferred less (Manning, 2009).

During peak visitor season, traffic congestion has been a major issue. The subsidiary issues range from difficulty trying to find parking at popular tourist destinations to temporary road closures. When a road or a parking lot becomes gridlocked, it poses a safety threat, prohibiting emergency vehicles from reaching the visitors if an emergency was to arise. When congestion reaches the point of posing such a safety threat, the park rangers are forced to temporarily close the roads. John Kelly, Acadia National Park management assistant, suggested that Cadillac Summit Road, in particular, had to be shut-down on a regular basis due to gridlock at the summit. Unlike most other popular areas in the park, Cadillac Summit Road is the only access road to get up to Cadillac Mountain. Visitors must travel up Cadillac Summit Road to reach the summit and then drive back via the same way they came. Last year, Cadillac Summit Road was closed forty-nine times from June 28th to September 4th with closure times ranging anywhere from thirteen minutes to an hour and a half (Acadia National Park on my Mind, 2017).

Temporary road closures not only take away from the visitor experience, but also requires a lot of manpower. Currently, ridgerunners and rangers oversee the popular areas and alert other rangers in the park when traffic is reaching maximum capacity. In extreme cases, illegally parked cars have to get towed when they prevent buses or cars from leaving the overcrowded areas (Kelly, 2018). Traffic congestion and the subsequent road closures can be problematic for visitors who come to a National park to visit certain areas, only to find out the paths are blocked upon arrival (Bianchi, 2018).

Right-hand lane parking has also contributed to traffic congestion issues. In the 1970s, part of the Park Loop Road was changed from one-lane two-way traffic to two-lane one-way traffic. As a result of this change, people started parking along the side of the road, occupying one of the two lanes. Since traffic could still get through in these two-lane one-way regions, the park decided to allow right-hand-lane parking for this section of the park. However, since the park sanctioned such behavior, visitors assumed parking on the side of the road is permitted in other areas in the park as well. Such behavior further contributes to congestion issues (Kelly, 2018).

2.2 Project Overview

The main goal of our project was to determine the feasibility of webcam usage in congested areas of the park as a means to monitor traffic. The model developed in this project is meant to serve as a benchmark for more extensive implementation of similar methods in the future. Four subsidiary steps were accomplished to determine the capabilities and limitations of webcams as they pertain to the park. Firstly, we identified several of the most congested areas around the park by reviewing past documents and ranger recommendations. Secondly, different cameras on the market were studied and compared for an appropriate selection process. We then tested if the camera of choice was able to record and transmit real-time footage in the areas identified in the first objective. Thirdly, the captured time-lapse photos were shared with park officials. Finally, feasibility of a wide-scaled implementation of the process described above was evaluated by looking at cost, cellular connectivity and camera performance.

2.3 Webcams as a Solution

Many national parks have been using webcams for years in order to monitor wildlife, natural landscapes, weather patterns, and visitor traffic. For example, Katmai National Park has several webcams, such as the Lower River Cam, used to monitor bears and other wildlife. Additionally, several parks, such as Acadia and Grand Teton, use webcams as a means to monitor air quality and weather (All U.S. National Park WebCams, 2017). General landscape pictures and videos are taken by webcams in almost every other major national park in the United States (All U.S. National Park WebCams, 2017). These webcams are used to improve the visitor experience by offering visitors a tool to access additional information about the park.

Yellowstone is one of the leaders regarding webcam usage in national parks. The park has nine webcams that stream images on its website. In addition to the Old Faithful Geyser live stream, the park has eight other static webcams that upload new images every thirty seconds. The park uses a Canon VB-H41 camera, which transmits images through a T1 fiber optic line. Since the cameras are linked to computers through cables, the transmission line limits the total number of possible camera locations (National Parks Service, Webcam FAQ, 2017). The Canon VB-H41 is a high definition camera capable of recording high quality videos. However, the fiber optic line only allows for the transmission of a relatively low-quality video that the visitors see. Yellowstone is also a pioneer in using webcams to aid in traffic monitoring. Three of the parks static webcams overlook parking lots or entrance ways. Specifically, the park has cameras monitoring the north entrance, the west entrance, and the Old Faithful parking lot. Unfortunately, we were not able to determine if these cameras are used to monitor traffic, weather conditions or parking availability (National Park Service, Webcams, 2017). Our project aimed to expand on camera systems implemented in other parks by giving park officials and visitors real-time feedback on the visitor traffic in the park, as well as develop a webcam system that can be implemented almost anywhere in the park.

As with most national parks, Acadia also has a history of camera use. Currently, the park has both webcams and security cameras. However, cameras that could be used to monitor visitor traffic, such as the camera at Sand Beach, have not been working for years. Due to personnel changes and the high cost of maintaining the security cameras, the park decided to cease operating the system (Bianchi, 2018). Although a large number of cameras are not in use, the park does maintain a couple of cameras. The functioning cameras are mainly used for monitoring the weather and other natural occurrences in the park. For example, there is a webcam that refreshes every fifteen minutes on McFarland Hill. This webcam, which can be viewed in real time on the NPS website, is an air quality monitoring system. The camera takes images looking at haze and air pollution in the park, while providing information on ozone levels, temperature, wind, visibility, humidity and precipitation. On a clear day, the camera has a visibility range of 153 miles from its perch 518 feet above sea level. Below is an example image of the landmarks that are visible from the webcam on McFarland Hill (National Park Service, Acadia National Park, 2018).

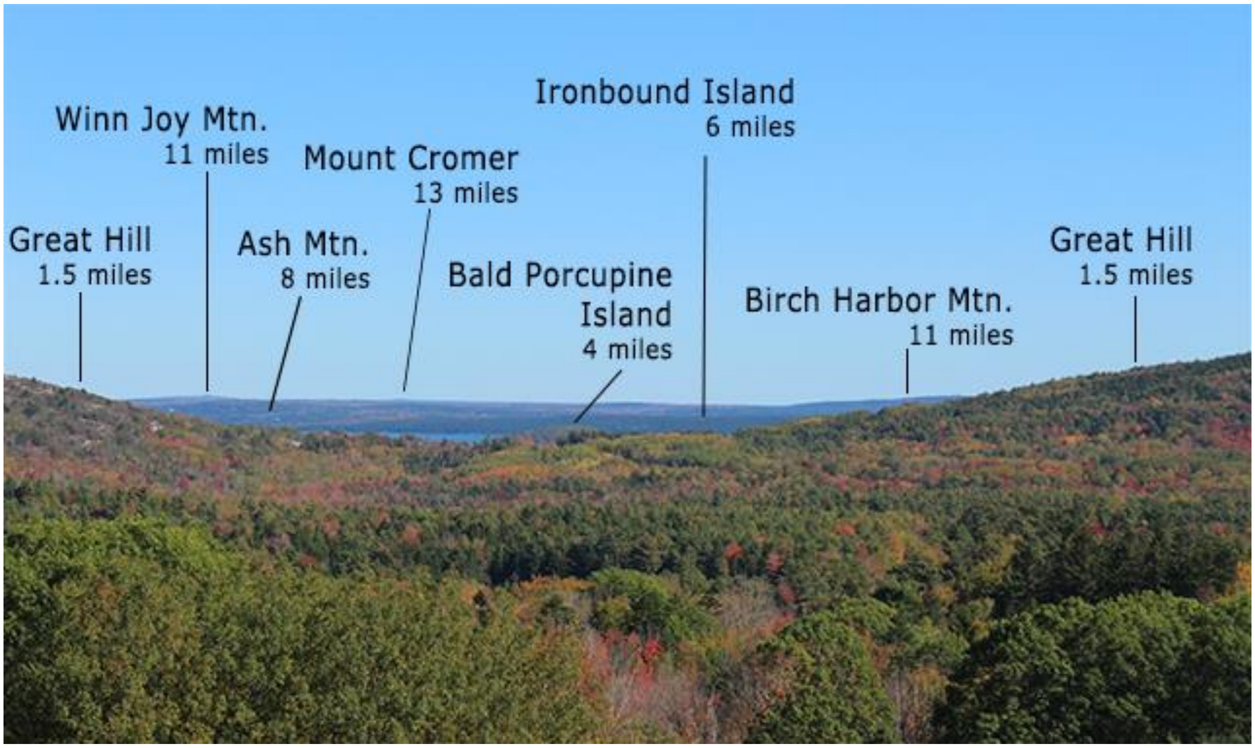

Figure 1: View from McFarland Hill

The view from the webcam on McFarland Hill shows that a webcam can produce high quality imaging and videos. Along with the air quality monitoring camera on McFarland Hill, Acadia has employed other methods to monitor different aspects of the park. For instance, Eye on Acadia, a webcam project initiated by the park, provided insight into our project. The Eye on Acadia webcams, which are still under maintenance, are used to monitor scenic aspects of the park. These webcams are cellular connectivity driven and powered by solar or small wind turbines (National Park Service, Eye on Acadia, 2017). Similarly, our project instituted a webcam system that can be powered anywhere in the park through the use of solar panels, while allowing users to access the images anywhere as long as cellular connectivity was available.

There are a few possible approaches in regards to choosing software and cameras to monitor park traffic. Park officials need constant updates to efficiently make the appropriate closures of parking lots and congested areas. This requirement means that park officials need a network that can transfer images in real-time to be viewed quickly. Spypoint Link-S, the camera of choice for this project, has proven to fulfill such a requirement. The camera and its built-in network can capture and update photos in a cloud storage system for easy access as frequently as every three minutes. Another approach was to build a webcam with a Raspberry Pi computer (Raspberry Pi Foundation, 2018). The Pi camera, given its programmable feature, is capable of setting up an FTP server and update photos directly to the park's website. The real-time image can then be viewed by both rangers and visitors.

2.3.1 Cellular Connectivity

Cellular connectivity is required to transmit images in real-time without the use of T1 transmission lines. The National Park Service does not have a national policy regarding cell towers, nor does it track the construction of cell towers within national parks (Leavenworth, 2017). As a result, cell towers exist near or within national parks, but cell signal is usually poor due to a limited number of towers and extreme topography that reduces signal strength (National parks next generation, 2017). Below is a map containing the locations of all the cell towers on the island.

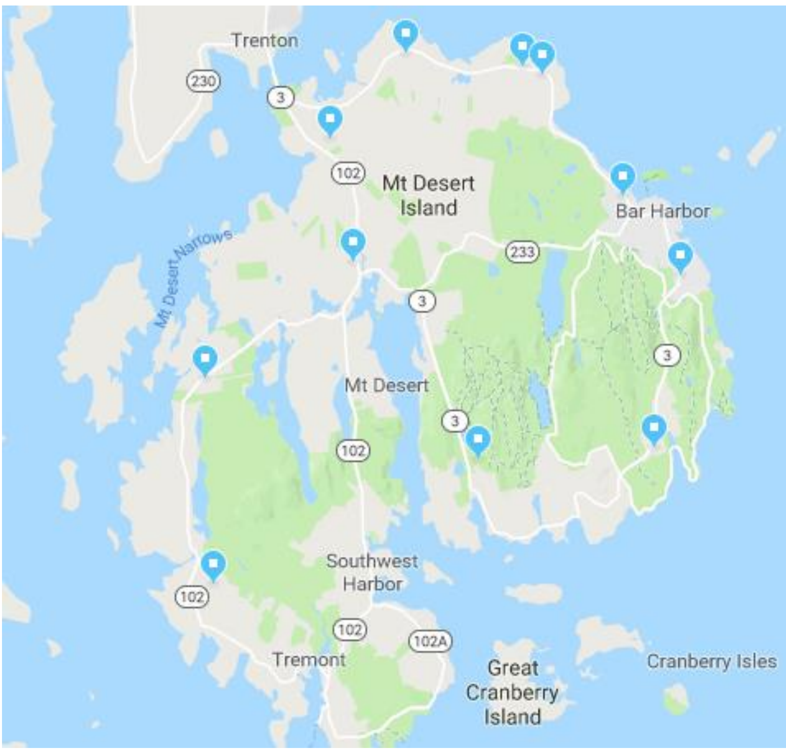

Figure 2: Map of Cell Towers on Mount Desert Island

Cell signal strength is measured in decibels. Signal strength can range from -50dBm, which is perfect signal, to -120dBm, which is very poor to no signal (How to read cell phone signal strength the right way, 2018). As a general rule, transmitting images requires cell signal strength to be better than -120dBm. One thing to note about cell signal is that decibels aren't the only factor determining whether someone could get cell phone service. The weather, other users on the network and terrain are just a few examples of factors affecting connectivity (Guinness, 2017). Below is a map portraying AT&T connectivity throughout Mount Desert Island (Cellular Connectivity Team, 2018). Most of the Island has poor to moderate signal strength. Inconsistent image transmission led our group to explore options that could boost cell signal, such as a signal boosting antenna, in order to transmit images in places where we normally could not.

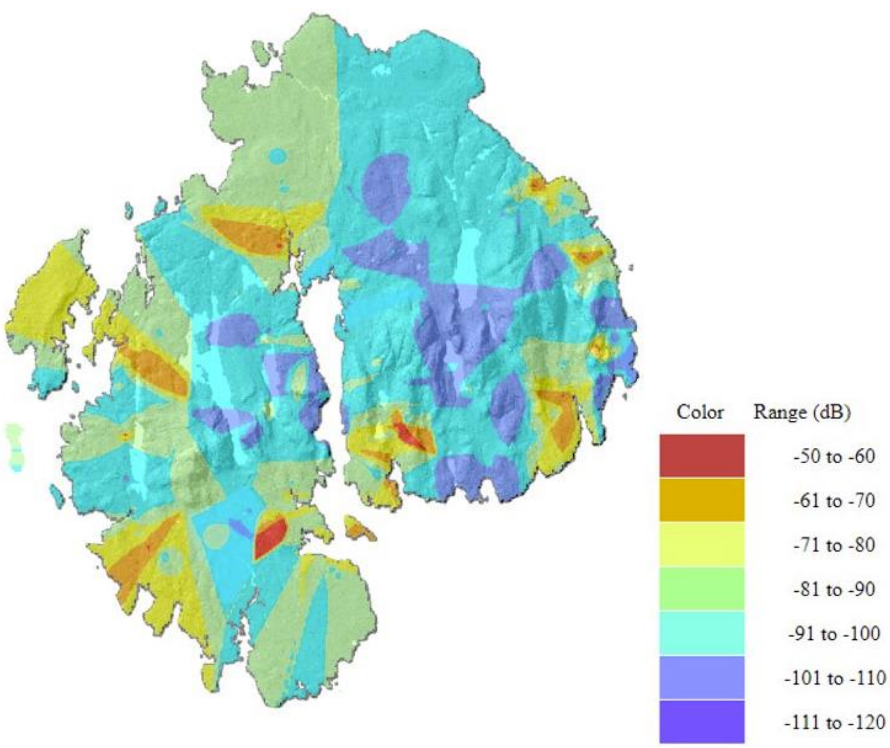

Figure 3: Heatmap of Cellular Connectivity on Mount Desert Island

2.3.2 Cost of Webcams

We decided on a trail camera called the Spypoint Link-S. Equipped with premium features such as solar accessory and cellular module, this camera retails for around $500 on the Cabela website. To aid our photo transmission, we purchased the $80 Spypoint range boosting antenna. Additionally, the Spypoint has a fee of $25 a month to take unlimited pictures and obtain access to all the features on the server. The second approach, the Raspberry Pi camera, is significantly less expensive. Our setup, which includes the motherboard, camera module, and micro SD card, cost around $100. However, more accessories such as solar panel and cellular module would need to be purchased and installed for all intended purposes. Overall, webcams as a solution are expected to reduce the need for manual labor. Compared to manual traffic tracking, webcams only require basic inspection and maintenance after the installation phase (Andrew, 2007).

2.3.3 Visitor Rights and Ethics of Webcams

It is unlikely that the implementation of webcams in Acadia National Park will violate the privacy rights of the visitors. In the United States, filming in public is generally allowed and no explicit permission is required in areas where there is no expectation of privacy. Visitors in public areas of the park share limited privacy rights; photographers are legally entitled to record tourists and objects without consent in a public place such as streets and public parks (Miles, 2015). Although the National Park Service established regulations regarding commercial photography and the need to gain permission, these regulations are unlikely to apply to our project or other NPS webcam research (Schneider, 2017).

3.0 Methodology

The goal of our project was to test the feasibility of webcams traffic monitoring in the congested areas of Acadia National Park. Our purpose was to determine whether webcams could aid rangers in traffic monitoring as well as oversee the effects of implementing reservation systems in the draft transportation plan. To achieve this goal, four subsidiary objectives were accomplished:

Objective 1: Identify the most congested areas in the park.

Objective 2: Purchase and setup webcams to monitor traffic conditions.

Objective 3: Share the recorded images with park officials.

Objective 4: Evaluate the feasibility of a webcam network.

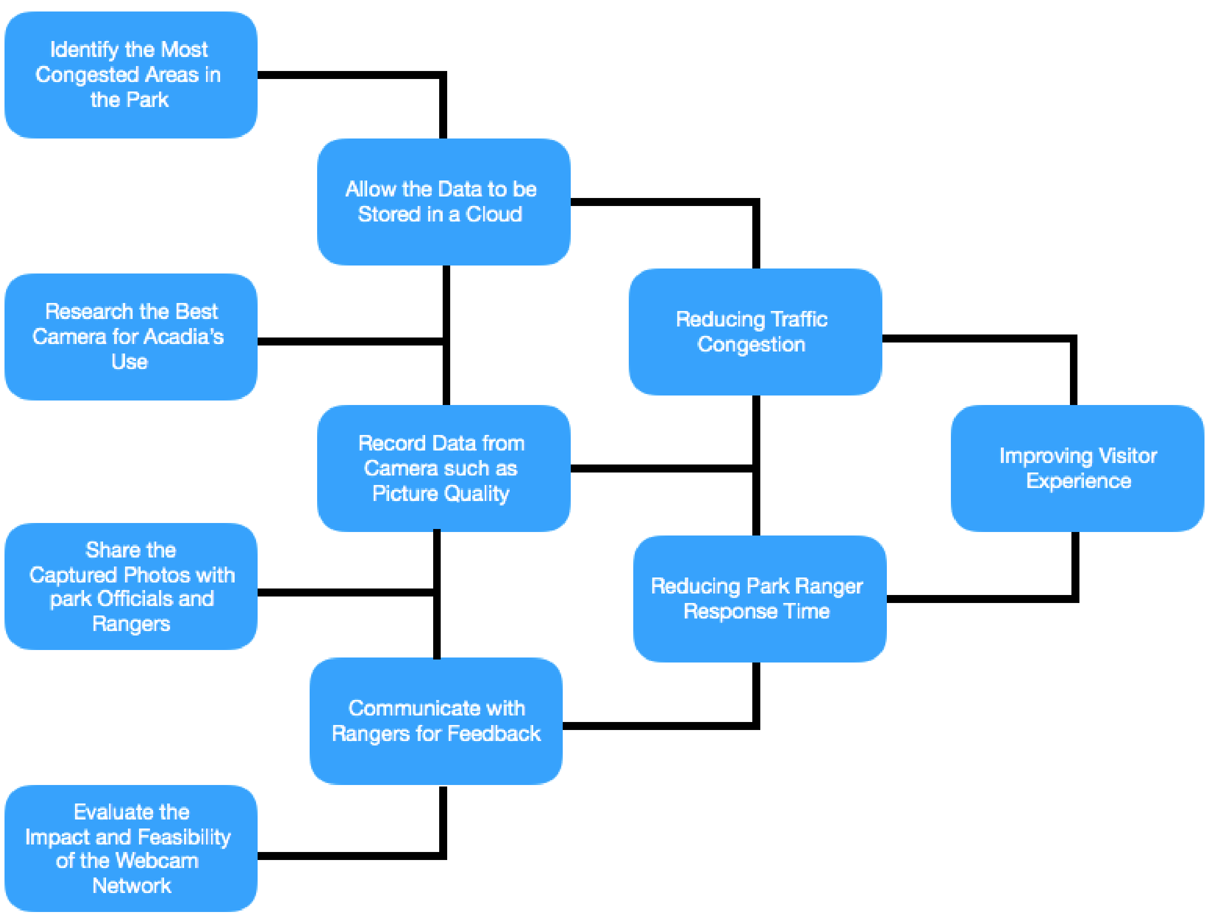

Figure 4: Workflow of Ideas

3.1 Objective 1: Identify the Most Congested Areas in the Park

We decided to focus our efforts on the most congested areas of the park, since webcams would be most beneficial at these locations. Some of the most congested areas include Cadillac Mountain, Thunder Hole, Sand Beach, and Jordan Pond (Manning, 2009). Information from Manning's study aligned with the feedback we received from park Ranger John Kelly. Kelly suggested we place the camera at Cadillac Mountain, Sand Beach, Jordan Pond, Bass Harbor Head Lighthouse, Echo Lake Beach, and Hulls Cove Visitor Center (Kelly, 2018). In addition to these sites, we decided to test the camera at Mill Field, Gilley Field, Beech Mountain, Acadia Mountain, Thunder Hole, Otter Cliff, Otter Point, and Bubble Rocks. Below is a map of all the locations tested.

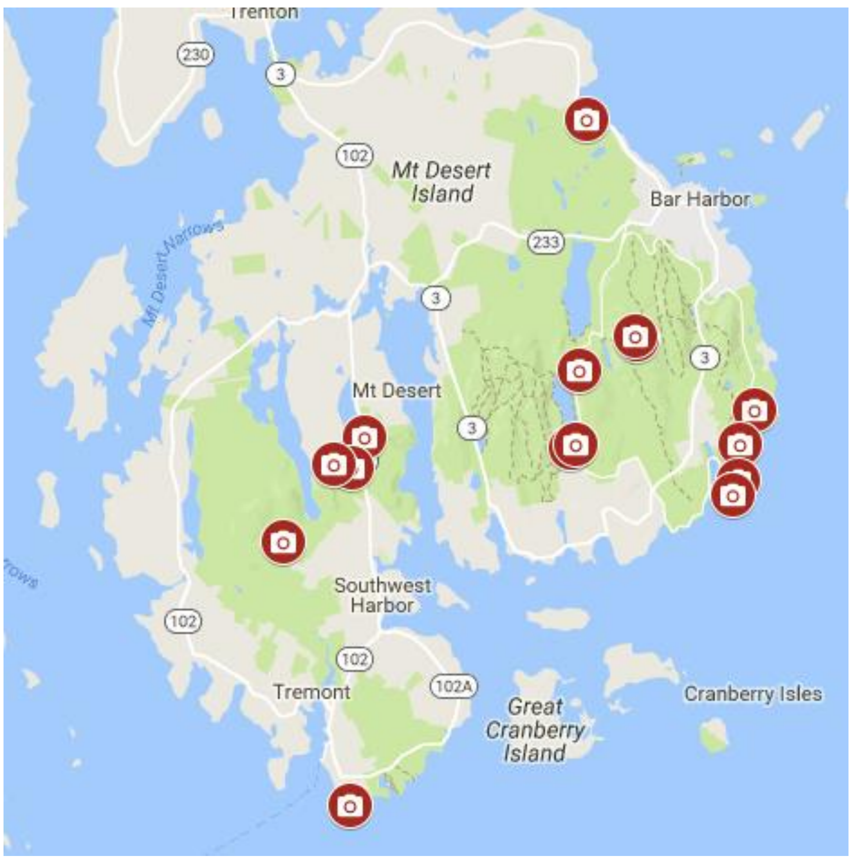

Figure 5: Camera Locations Tested

Given its popularity, Cadillac Mountain was chosen as the first test site (USNews Travel, 2018). The camera was left along Cadillac Summit Road for a little over a week, in order to evaluate the camera's long-term capabilities. At first, the camera was placed at the intersection of Cadillac Summit Road and the entrance to the Blue Hills Overlook. This site was chosen, because it is the benchmark rangers use to determine when the road needs to close (Kelly, 2018). As per Kelly's suggestions, the camera was moved closer to the summit of Cadillac Mountain, approximately 1,000 feet down the road from the entrance to the Cadillac Mountain parking lot. The new placement provided a better view of Cadillac Mountain Road, making it more conducive for capturing congestion on the road.

After testing the camera on Cadillac Mountain, our focus shifted from testing the long-term functionality of the camera to its ability to monitor traffic in a wider array of situations and locations. Specifically, we were interested in the camera's signal capability at the other locations. We tested the camera for roughly thirty minutes, evaluating if the camera was able to transmit images to the cloud server. Furthermore, we captured images from various points in the parking lots to determine the optimal webcam placement.

3.2 Objective 2: Purchase and Setup Webcams to Monitor Traffic Condition

The second step towards constructing a demo webcam system was the selection and purchase of the camera. Three camera options were examined to determine the best fit. Jay Elhard, the interpretive media specialist from Acadia National Park, suggested we inspect the NETGEAR Arlo Go security camera (Elhard, 2018). This camera proved to have many issues that we were unable to resolve. Next, we looked into the possibility of building a Raspberry Pi webcam. Lastly, we looked into the Link-S trail cam from Spypoint as an off-the-shelf solution. Due to issues with programming the Raspberry Pi camera, we selected the Spypoint Link-S for the purposes of this project.

Intended to be used as a remote security camera, Arlo Go offers some good features for implementation in a national park. The camera is slightly larger than a billiards ball, resulting in less intrusion to the landscape. A camouflage cover can be installed to further conceal the device, while providing additional protection from different weather conditions. After installing the premium accessories, Arlo Go can be powered by solar panels and accessed via cellular data. Therefore, little maintenance is required from the park rangers other than regular inspection and calibration. In terms of functionality, Arlo Go provides real-time streaming option through its own server.

Despite the benefits the Arlo Go could offer, there are issues that hindered its implementation. Firstly, only one user can access the camera's cloud server at a time, meaning that only one ranger could view the stream from the camera at a time. Additionally, to access the footage from the Arlo Go iPhone App, the viewer must be connected to Wi-Fi (Elhard, 2018). As a result, a ranger working in the park would not be able to access the real-time footage using cellular connection. Moreover, according to Arlo Go's user manual, the solar battery is programmed to stop charging below freezing temperature to protect the device (Courtney, 2017). As a result, the camera could lose power much earlier than intended. Due to the significantly lower visitor volume during the colder seasons, however, we do not expect such temporary failure of the monitoring network to be of much concern (Walsh, 2017). The Arlo Go is also not FTP compatible so any data it takes cannot be directly uploaded to the park's website. The Arlo Go only records videos, which is a large amount of data to transfer and analyze. Lastly, this camera is the most expensive option. The base cost is $400 and a $20 monthly plan is required to access the cloud server. Another $200 is required to purchase the solar panel and weather resistant skin.

The second camera we considered was a Raspberry Pi based camera. This is a programmable camera that can take pictures at a set time interval. The major upside of the Raspberry Pi camera is its FTP compatibility, which allows the photos taken to be uploaded to the park's website. The camera is also the cheapest option. There are still some disadvantages to the Raspberry Pi camera. The major obstacle being that the camera is not an off-the-shelf solution. A programmer needs to code the camera and develop a cloud server where the camera can transmit images. Furthermore, the camera needs additional accessories to function in the park, such as weather proof container, solar panel, and the cellular module.

Figure 6: Raspberry Pi Camera Module and Motherboard Setup

After comparing the cost and functionality of the three cameras above, we decided to use the Spypoint Link-S as the primary camera for this project. The most notable features of the Link-S are the time-lapse mode, the mobile app, and the internal power supply. When set to time-lapse mode, the camera can capture images continuously in intervals from three minutes to twenty-four hours. To reduce unintended power usage, the Spypoint can be set to work in a specified schedule. For example, to monitor traffic on the Cadillac Mountain Summit Road during sunrise and sunset, we adjusted the camera to run from 4AM to 9PM. While the camera takes color photos during daytime, a night mode is automatically activated to capture infrared photos in low light conditions. With each image captured, a time stamp documents the date, time, moon phase and temperature on the bottom of the image.

The mobile app offers a practical means for the park officials to closely monitor traffic conditions. Supported by major network carriers such as AT&T and Verizon, the Spypoint uploads all captured images to its own cloud server. These images can be viewed by any users with the login credentials on PC at myspypoint.com or on the IOS and Android App named

Spypoint Link. For our project, we selected AT&T as our network carrier. With cellular connection, rangers working in the field can access these visual traffic updates at any remote locations that have signal. Additionally, via the mobile app, rangers can remotely access information such as device location, signal strength, battery percentage and camera settings. However, the Spypoint is not FTP compatible so data cannot be posted directly onto the park's website.

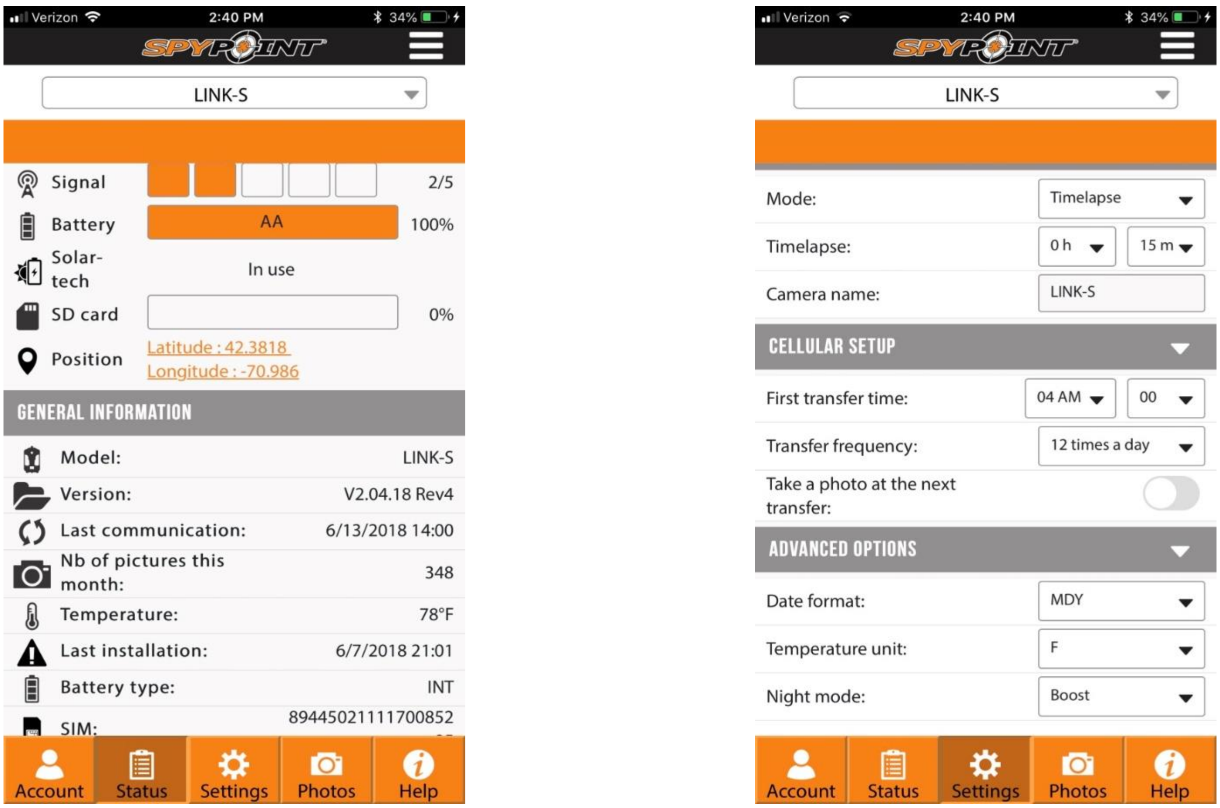

Figure 7: Demonstration of Features Available on Spypoint Link Mobile App

Designed to work as a trail camera, the Link-S has many desirable features that allow it to work independently in an outdoor environment. The camera comes with a built-in solar panel, which charges an internal rechargeable battery. There is also the secondary option to add eight AA batteries as a backup power supply. Little maintenance is required other than regular inspection and calibration. The Link-S can be set to upload new photos every time an image is captured. Working at this upload frequency puts more strain on the power consumption, but it provides the most up-to-date information. Along with the cellular module, the Spypoint camera allows for a convenient installation and a completely wireless setup.

The Spypoint Link-S comes with an installation strap and a mounting bracket. The mount provides rounded edges for a more secure installation. The camera has a camouflage finish that conceals the device and reduces intrusion to landscape. Next to the camera, we placed a tag provided by NPS, claiming the device is set up for research purposes. We locked the camera in place with a set of metal chains as an additional anti-theft measure.

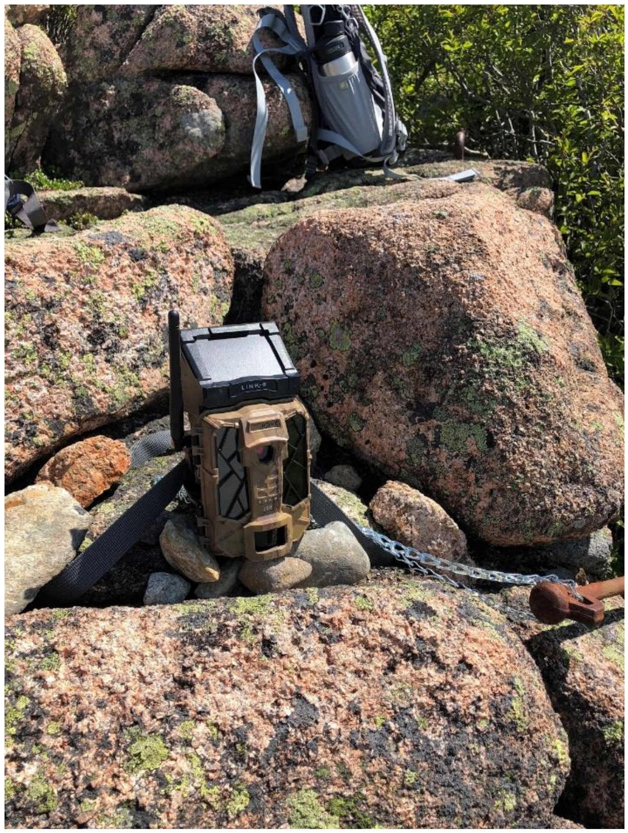

Figure 8: Spypoint Camera Installation on Cadillac Mountain (Research Tag Not Shown)

Spypoint offers a long-range signal boosting antenna as an upgrade from the stock antenna. The booster antenna comes with a sixteen-foot cable. To raise the antenna, we purchased a twelve-foot extendable painting pole, in which we mounted the camera midway and the cell boosting antenna at the top. This setup provided easy portability, especially since we needed to lift the antenna to increase signal strength. There are two images portraying our setup on the next page.

Figure 9: Camera Setup with Long Range Boosting Antenna

Figure 10: Example Setup in the Field

Below is a table showing aspects of the three cameras discussed. The Spypoint was chosen after weighing the strengths and weaknesses of all three cameras.

	Cost	Cloud Server Cost	Cloud server access	FTP Compatibility	Built-in Solar Power	Built-in Weather Protection	Camera Quality	Ease of Use	Major Flaws
Arlo GO	$400	20/Month	1 person at a time	No	No, a solar panel accessory can be purchased	No, a weather resistant skin must be purchased	ONLY VIDEO	Limited access	Not FTP compatible, limited cloud access, only captures video
Spypoint Link S	$500	$25/Month	Anyone	No	Yes	Yes	12 MP	Mobile app controlled	Not FTP compatible
Raspberry Pi	$125	Free	Anyone	Yes	No, a solar panel accessory can be purchased	No, a weather resistant skin must be purchased	8 MP	Laptop Controlled	Requires coding experience

Figure 11: Comparison of Webcam Systems

3.3 Objective 3: Share the Recorded Images with Park Officials

Regular updates of the project and sample photos were sent to Rebecca Flesh, our project correspondent, and park officials Abe Miller and John Kelly. The login credential was provided to the officials to view our Spypoint photos in the cloud server. In return, we received feedback on camera placement and image quality. For example, our team moved our camera back 150 feet from our initial installation on Cadillac Mountain, because of feedback from John Kelly. Sharing images with rangers and Friends of Acadia officials also lead to input on valuable sites previously unknown to us, such as the Beech Mountain parking lot.

3.4 Objective 4: Evaluate the Feasibility of the Webcam Network

The last objective was to evaluate the feasibility of the webcam system as a long-term solution to traffic monitoring. In order to determine the capabilities of the webcam, we focused on testing the camera's battery life and ability to transmit images throughout the park. When testing the camera on Cadillac Mountain, we collected data regarding daily cloud cover, precipitation, battery percentage and image quality. These data points were sourced from the camera's cloud server and mobile app.

We also evaluated the cellular connectivity of the camera. To examine the effect of the range boosting antenna, we captured images with both the stock antenna and the range boosting antenna. Each time an image was captured, the Spypoint recorded the webcam signal strength on a built-in data log stored on the SD card. The data on signal strength generated with both antennas were sorted for comparison. Furthermore, we recorded signal strength from an Android cell phone to compare against the stock antenna signal strength.

3.4.1 Data Analysis

Quantitative results, obtained from the data log stored in the camera, were compiled in an Excel spreadsheet. These data helped determine the feasibility and usability of a webcam network in Acadia. Battery percentages were used to determine the potential of a solar panel to power the camera in locations without direct power sources. Daily cloud coverage and precipitation data were useful in evaluating the webcam's ability to withstand inclement weather conditions. Specifically, we attempted to find a correlation between cloud coverage and the fluctuation in battery percentages on a certain day. The image quality data points were used to determine the consistency of the camera and the effects of inclement weather on the webcam's ability to function properly. The image quality was rated twice a day on a scale of one to five, with five representing perfect clarity and one representing almost no visibility. Data points on cellular connectivity confirmed if a camera could transmit images wirelessly under the overall weak cellular service in the park. Lastly, the data on cellular signal were revisited, in order to determine the effects of the cell boosting antenna.

4.0 Results

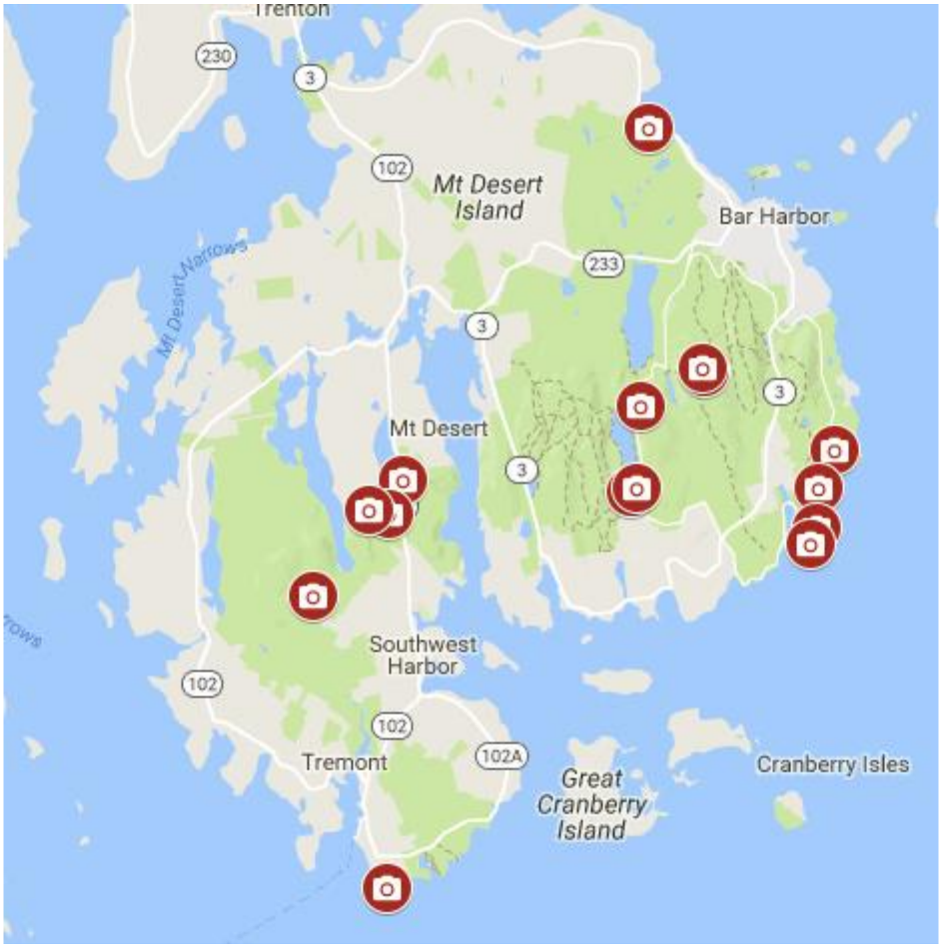

Figure 12: Camera Locations with Range Boosting Antenna

The camera was able to transmit images with the range boosting antenna at all locations tested.

Daily Precipitation and its Effects on Picture Quality of the Spypoint Link-S		
	Daily Precipitation (inches)	Average Picture Quality (1-5 scale with 5 being best)
June 23	0.09	2.50
June 24	0.01	2.00
June 25	0.57	3.00
June 26	0	3.50
June 27	0	3.50
June 28	2.21	1.50
June 29	0	2.00

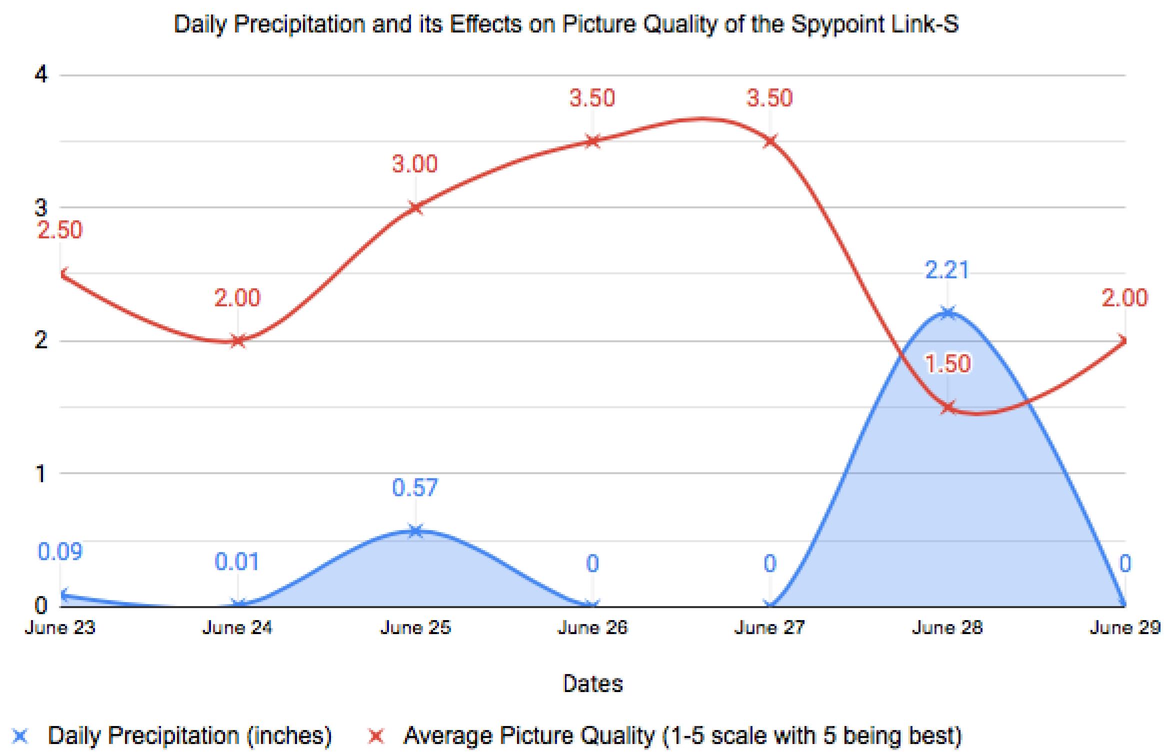

Figure 13: Daily Precipitation and its Effects on Picture Quality of the Spypoint Link-S

Sky Coverage's Effect on the Battery of Spypoint Link-S		
	Battery (%)	Sky Cover (%)
June 23 am	99	65
June 23 pm	82	65
June 24 am	70	89
June 24 pm	85	89
June 25 am	83	72
June 25 pm	72	72
June 26 am	59	12
June 26 pm	52	12
June 27 am	54	16
June 27 pm	45	16
June 28 am	43	96
June 28 pm	40	96
June 29 am	43	61
June 29 pm	59	61

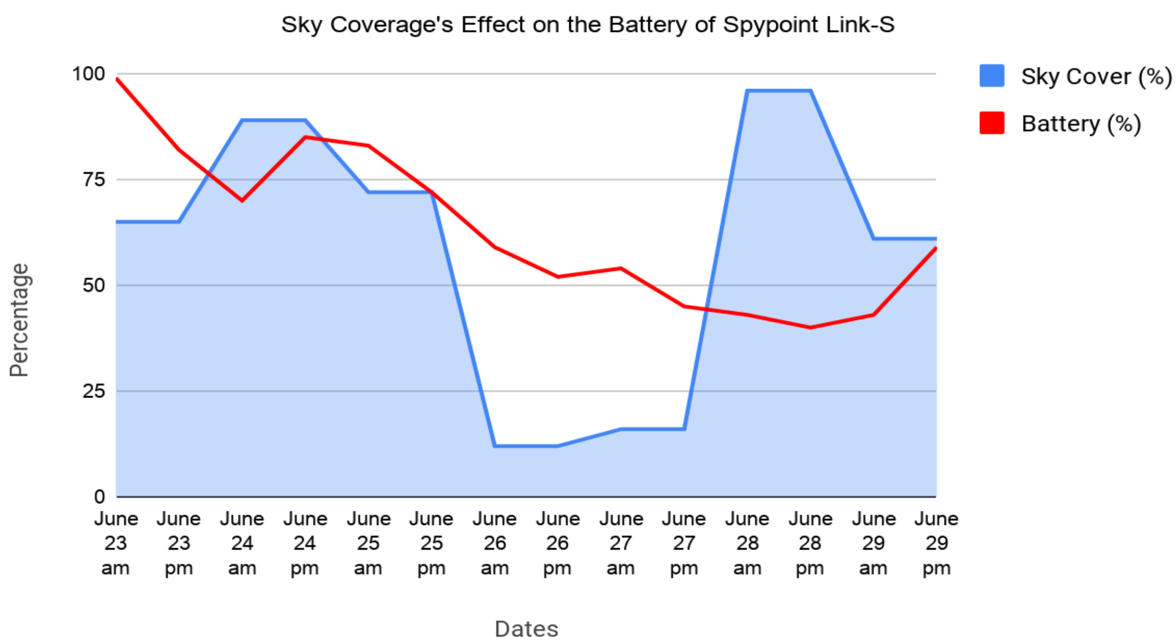

Figure 14: Sky Coverage's Effect on the Battery of Spypoint Link-S

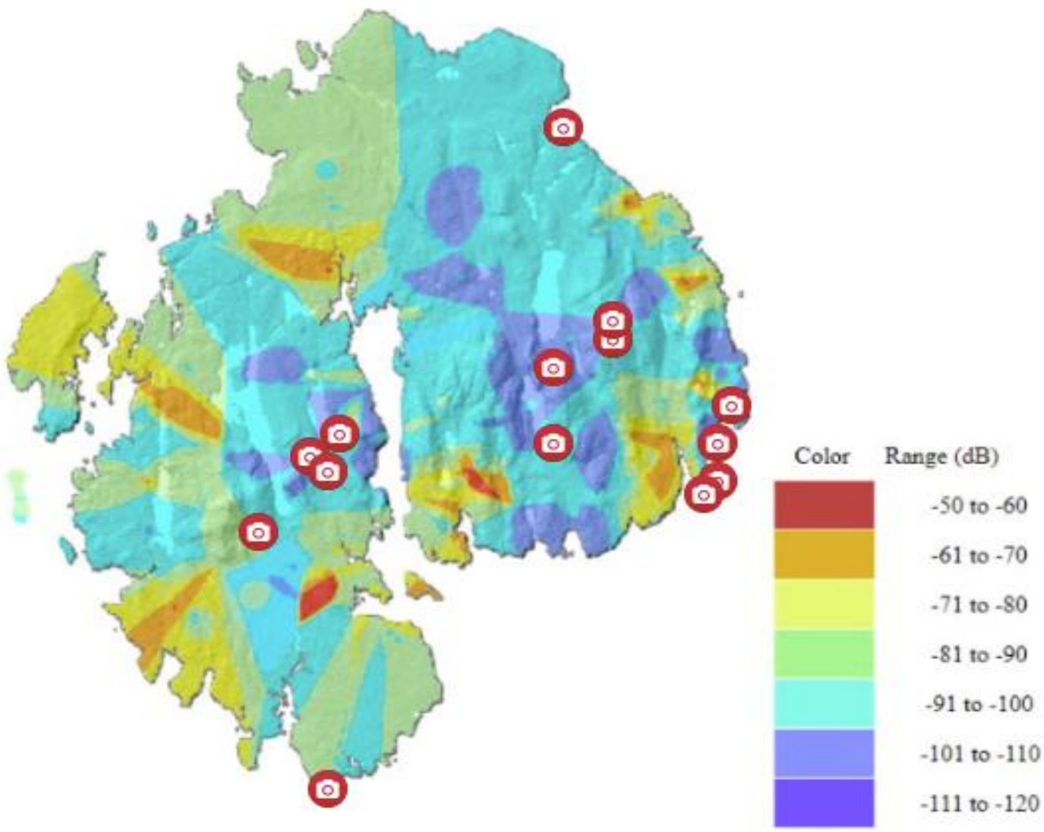

Figure 15: Locations of Spypoint and Cellular Connectivity

Average Camera Signal without Range Boosting Antenna vs. Average Camera Signal with Range Boosting Antenna		
Location	Average Camera Signal with Range Extending Antenna (-dBm)	Average Camera Signal w/o Range Extending Antenna (-dBm)
Cadillac Mountain	82	96
Bubble Rock	108	0
Jordan Pond	115	0
Sand Beach	107	0
Thunder Hole	113	123
Otter Cliff	86	103
Otter Point	73	86
Mill Field	89	97
Gilley Field	90	93
Bass Harbor Head Light	72	105
Beech Mountain	99	101
Echo Lake Beach	96	100
Acadia Mountain	106	106
Hulls Cove Visitor Center	88	90

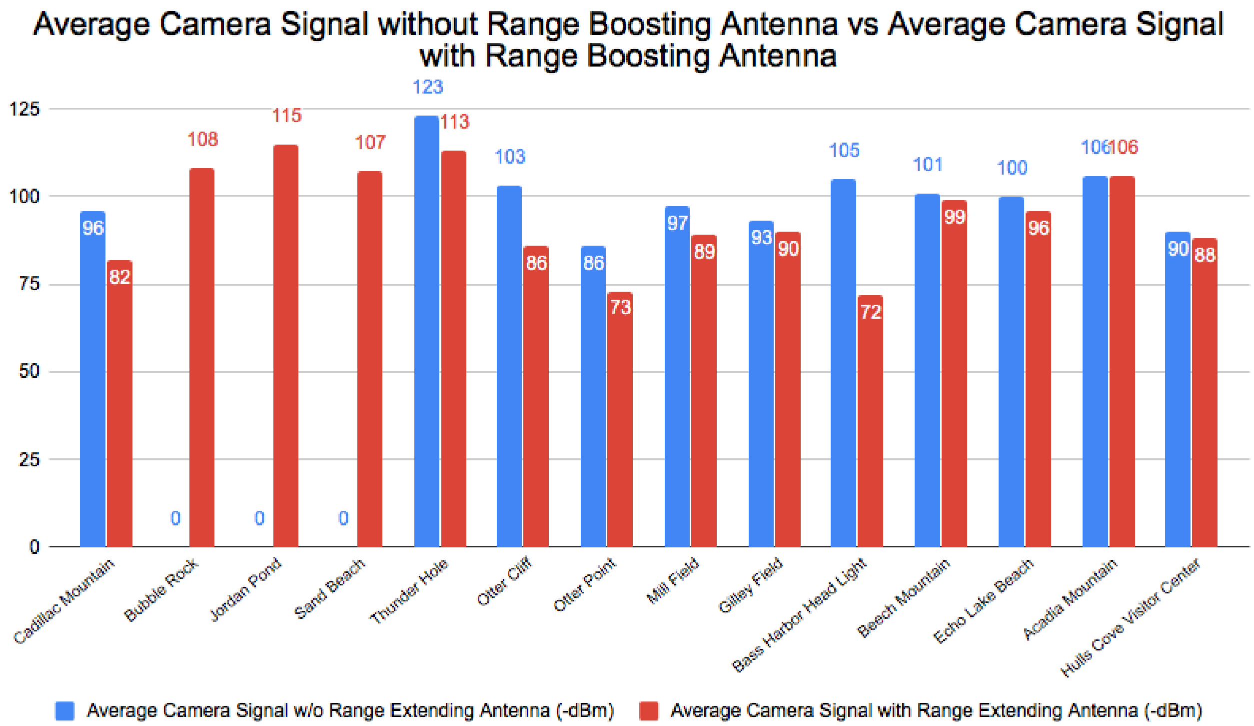

Figure 16: Average Camera Signal without Range Boosting Antenna vs. Average Camera Signal with Range Boosting Antenna

(zero indicates no signal)

Average Phone Signal vs. Average Camera Signal with Range Boosting Antenna		
Location	Average Phone Signal (-dBm)	Average Camera Signal with Range Extending Antenna (-dBm)
Cadillac Mountain	81	82
Bubble Rock	103	108
Jordan Pond	111	115
Sand Beach	0	107
Thunder Hole	111	113
Otter Cliff	93	86
Otter Point	79	73
Mill Field	96	89
Gilley Field	88	90
Bass Harbor Head Light	83	72
Beech Mountain	101	99
Echo Lake Beach	97	96
Acadia Mountain	101	106
Hulls Cove Visitor Center	85	88

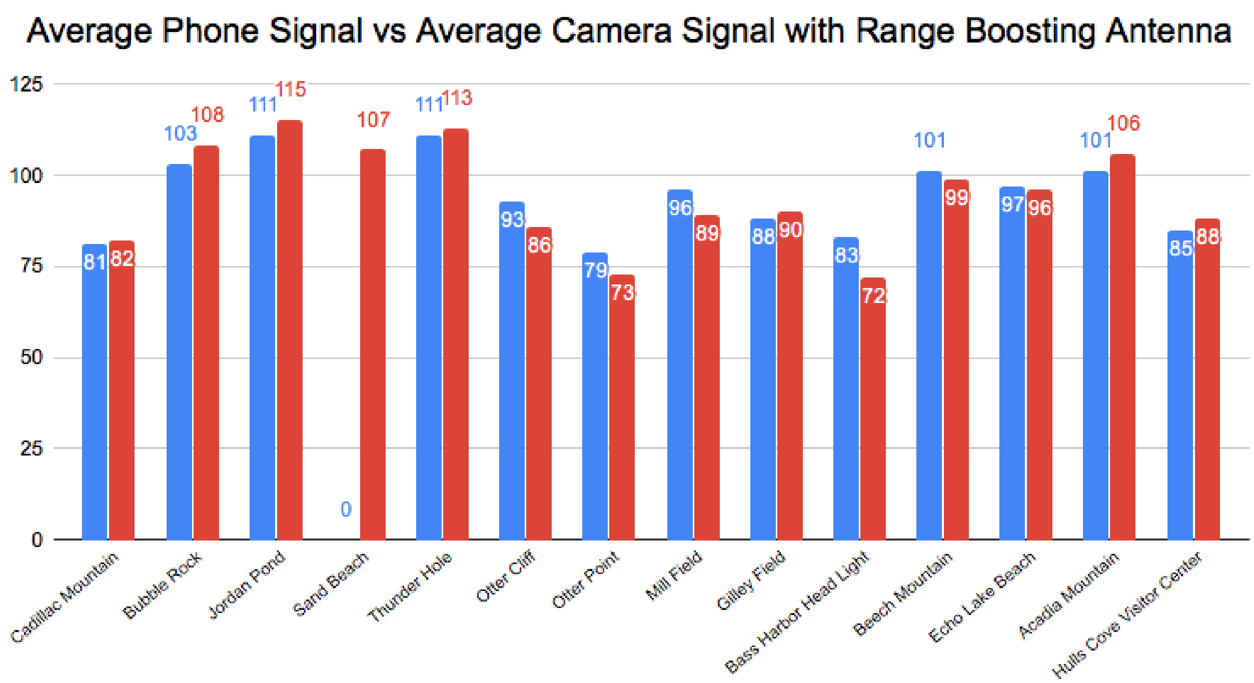

Figure 17: Average Phone Signal vs Average Camera Signal with Range Boosting Antenna

(zero indicates no signal)

5.0 Discussion

5.1 Findings Regarding the Spypoint Link-S

Overall, the Spypoint Link-S served our purposes of testing the feasibility of webcam traffic monitoring. Under normal weather conditions, the picture quality was satisfactory and allowed the viewer to see the traffic congestion. For some areas of the park, we were able to transmit images to the server using the short-range antenna provided with the camera. However, others required the use of a cell boosting antenna raised 12 feet above the ground. Nonetheless, with the use of the boosting antenna we were able to obtain enough cell signal to transmit images at all the locations we tested, even some that were deemed dead zones by park officials.

We learned that weather could greatly influence image clarity. When we left the camera out on Cadillac Mountain for a week, the camera was exposed to all kinds of weather. The image clarity was near indistinguishable when the camera was covered by condensation. This effect was especially noticeable for images taken in the dark with infrared mode. When comparing the amount of precipitation to the picture quality rating, we found as the precipitation increased, the image quality decreased. Fog was another issue affecting image quality. However, traffic congestion is expected to be less of an issue in poor weather. Some example images are below.

Figure 18: Effects of Rain on Spypoint

The battery life of the camera was another issue we encountered. Given the substantial number of pictures the camera was taking on Cadillac Mountain and a slew of overcast days, the battery percentage dropped from 83% to 40% over four days. If these cameras were to be implemented for long periods of time, they may need to be connected to a 12-Volt battery source, as a backup to the solar panel. To lessen the battery drain, another solution would be to reduce the amount of pictures taken on such days, since constant monitoring would not be as needed.

The use of the cell boosting antenna significantly helped our findings. When using the stock short range antenna, there were four locations where the camera did not receive any signal: Sand Beach, Thunder Hole, Jordan Pond and Bubble Rock. On average, the cell boosting antenna was about 14 decibels better than the short-range antenna. One thing to note is that not all the locations we tested would benefit from the use of a cell boosting antenna. Locations such as

Cadillac Mountain or Otter Point already have good signal and do not need increased signal strength. At the same time, we looked at how the cell boosting antenna compared to an Android phone with the same carrier. However, the results were inconclusive. At some locations, the cell boosting antenna received stronger signal, while the cell phone obtained better signal at the other locations.

Additionally, we learned that camera placement for long-term camera use should be carefully considered. When monitoring parking lots, the best place to position the camera is in corners overlooking the entire lot. Given the large number of pictures the camera needs to take in certain areas of the park, it is necessary that the camera is placed in an area where it gets a substantial amount of sunlight. Another element to consider is the height in which the camera needs to be raised for effective monitoring. Parking lots that are slightly dome shaped, such as the ones found at Thunder Hole and Otter Point, require the camera to be placed higher in order to view the entire parking lot. Given the requirements for acceptable monitoring, camera poles may need to be installed in certain locations, such as Cadillac Mountain and Thunder Hole.

Site Specific Information

Locations	**Is the Signal Boosting Antenna Required?**	**GPS Coordinates for Potential Camera Placement**	**Other Comments**
Cadillac Mountain	No	Along the right side of the road leading up to the Summit, facing the Blue Hills Overlook. 44.350613, -68.229074	Cadillac Mountain gets a good amount of sunlight when the weather is good. Rangers would likely benefit from having two cameras to get a better view of the traffic congestion. Additionally, the park should purchase a camera pole in order to obtain the best pictures, while keeping the camera secure.

Bubbles Divide Trail	Yes	Near the exit, facing the entrance 44.340900, -68.250537	Bubbles Divide Trail is in the valley and therefore receives very poor signal. There is also significant tree cover, so the camera may not receive enough sunlight. Due to the narrow path, illegal parking could block the bus from entering the stop. Webcam monitoring will likely be beneficial at this location. In terms of camera placement, the camera should cover the entrance and exit.
Jordan Pond	Yes	Facing the road to the south of the Jordan Pond entrance; 44.321915, -68.251373 The south corner of the main parking area. 44.321016, -68.251839	Jordan Pond is in the valley and therefore receives very poor signal. It does however get plenty of sunlight for the solar panel. There are lots of tall trees that could be used as poles to secure the camera. Lastly, there are several large, separated parking lots requiring multiple cameras to monitor all of them.
Sand Beach	Yes	Mount the camera on the existing camera pole 44.330542, -68.183998	Sand Beach already has a 30-foot camera pole with solar panels, which would be an excellent place to hang a camera. The parking lot also has varying heights at which cars can park, making it essential that the camera is placed high up to overlook the lot. The park should consider using multiple cameras in order to monitor the whole parking lot as well as part of the road leading up to Sand Beach.
Thunder Hole	Yes	Face the exit and overlook the entire lot from the entrance, which is on higher ground 44.321597, -68.189084	The Thunder Hole parking lot is domed shaped. The camera needs to be placed high up to view the entire area. This parking lot would likely require a camera pole. The cell signal is weak, but there should be sufficient sunlight for the solar panel.

Otter Cliff	No	Face the entrance from the large rocks near the restroom 44.310617, -68.189863	Otter Cliff has strong signal strength, but there might not be enough sunlight for the solar panel. There are many tall trees that could hold the camera.
Otter Point	No	Overlook the lot from the entrance; plenty of room near the side of the road to install poles or utilize tall trees. 44.307575, -68.191755	Otter Point receives good signal strength and would likely receive enough sunlight for the solar panel. The parking lot is dome shaped and would likely require the camera to be placed higher up. There are lots of trees that could serve as good places to secure a camera.
Mill Field	No	Overlook the U-shaped path from the trailhead 44.295118, -68.363234	Mill Field receives strong cell signal, but sunlight might be an issue for the solar panels. This place experience very little traffic and probably does not need webcam monitoring at this time.
Gilley Field	No	Either entrance of the round parking lot should provide sufficient coverage of the entire lot 44.296599, -68.357153	Gilley Field receives strong cell signal, but sunlight might be an issue for the solar panels. This place experiences very little traffic and probably does not need webcam monitoring at this time.
Bass Harbor Head Lighthouse	No	Face the Lighthouse Rd from the bike rack 44.222580, -68.337574	Bass Harbor Head receives excellent cell signal, since there is a cell tower 30 feet away. The area seems to be consistently foggier than other areas, so solar power and picture quality might be an issue. The parking lot would benefit from having two cameras. One to look at the parking lot and the other monitoring the road leading into the parking lot. This lot would likely need a camera pole to mount the camera.

Beech Mountain	Yes	Face the lot entrance from the trailhead 44.315100, -68.343457	Beech Mountain has weak signal strength and likely receives insufficient sunlight for the solar panels. It does have tall, straight trees that could be used as poles to hang the camera. The parking lot would likely require two cameras, one for the parking lot and the other for the entrance road.
Echo Lake Beach	No	Face the lot from the bus stop; additional cameras can be added at the two islands at the turns of the lot 44.313528, -68.336689	Echo lake had moderate cell signal strength and sufficient sunlight for the solar panel. The parking lot is large with a sharp bend in the middle, likely requiring 3 to 4 cameras for full monitoring. One camera could be installed on the roof of the bus stop. The others may need camera poles.
Acadia Mountain	Yes	Place the camera south of the trailhead on the opposite side of the road to the parking lot 44.321361, -68.332878	Acadia Mountain has poor cell signal but gets lots of sunlight. The telephone poles could be used to hang the camera if one were able to get permission from the telephone companies. It may be difficult to monitor with cameras, because the cars can backup really far down the road. The park might want to place a camera north of the parking lot to monitor how far the cars back up.
Hulls Cove Visitor Center	No	Face the entrance and exit near the RV parking 44.409564, -68.247606	Providing parking for regular visitors and RVs, the Hulls Cove Visitor Center has one of the largest parking lots in Acadia. Should the park decide to install webcams, this location has excellent cellular signal and plenty of sunlight to power the solar panels. Multiple cameras are required to monitor the entire parking lot. Given the size of the lot, traffic could backup when visitors fail to locate available spots. Compared to webcam monitoring, parking capacity counting system, commonly used by hotels, would likely be more beneficial.

Figure 19: Site Specific Information

5.2 Cost Analysis

Our Setup Costs

Item	Cost
SPYPOINT Link-S	$499.99
SPYPOINT Cellular Trail Camera Booster Antenna	$79.99
12 Foot Extendable Pole	$33.98
Total	$613.96

Figure 20: Our Setup Costs

In addition to the one-time cost of purchasing the camera, the webcam network requires the purchase of a monthly plan for unlimited access to the cloud server. For our project, we subscribed to the three-month Hunting plan. The cost of the Spypoint plan would depend on whether the park wanted to monitor traffic outside of peak season.

Data Plan Costs

Plan	Cost per month	Number of months	Price
Annual +	$15	12	$180
Hunting	$25	3	$75
Hunting (2x)	$25	6	$150

Figure 21: Date Plan Costs

There are also additional Spypoint accessories that could potentially help fix the problems we discussed above. For example, Spypoint provides the option of a lithium battery pack that is supposed to last almost three times longer than traditional rechargeable alkaline batteries. There is also a 12-Volt solar panel that can be used to charge the lithium battery pack. One thing to note is that Spypoint does not recommend using the 12-Volt solar panel with other solar devices.

Below is a cost analysis for our proposed camera setup designed for long lasting battery life. The disadvantage to this setup is that it is much bulkier than the Spypoint Link-S webcam.

Proposed Long-Term Setup

Item	Cost
SPYPOINT Link-Evo	$249.99
SPYPOINT Cellular Trail Camera Booster Antenna	$79.99
SPYPOINT 12V Solar Panel	$39.99
12V Battery and Charging Kit (does not include power cable)	$34.99
12V Power Cable	$14.99
Lithium Battery Pack	$49.99
Total	$469.94

Figure 22: Proposed Long-Term Setup

6.0 Recommendations

6.1 Real-Time Traffic Analysis

Manual traffic counting is impractical due to its intensive labor cost. Automated vehicle counters can accurately measure the traffic flow through a particular road. The system usually utilizes some form of electronic equipment, such as the pressure-based recording tube built by another WPI team in 2016 (Tourist impact in acadia national park, 2016). However, it would be challenging for the park to respond to abnormal situations quickly when relying on the traditional vehicle counting method alone. For instance, the figures below show an RV that illegally entered and parked at the Sand Beach parking lots. A ranger patrolling the area issued a parking ticket to the RV upon arriving at the lot. In this case, the ranger suggested that it is difficult to determine how long the RV had been in the lot.

Figure 23: RV Blocking Three Parking Spaces at Sand Beach

Figure 24: Photo Captured by Spypoint from the Same Scene

Unlike car counters, which are unable to detect similar incidents, webcams allow for visual warning of unusual incidents. In future projects, it would be ideal to incorporate a system that utilizes computer vision. The Video Turnstile vehicle traffic counting system, developed by Retail Sensing, could potentially fulfill the technical requirement. Retail Sensing claims the Video Turnstile system is capable of achieving ninety-eight percent accuracy under different weather conditions. The system processes footage in real-time and updates the count result immediately through wireless connection. Moreover, the footage analysis is processed locally with build-in counting units, therefore data usage is greatly reduced. Similar systems and services are provided by companies such as Autostrade Tech, Intelligent Security Systems, and Picomixer (Syed, 2018).

6.2 Raspberry Pi Camera and FTP

In addition to sending real-time traffic report to rangers, the Acadia NPS hopes to provide visitors with information about congestion and parking availability (Notice of availability of the draft transportation plan and environmental impact statement for acadia national park, 2018). One solution, suggested by the Web Services Division (WSD), is to post public traffic warnings on NPS.gov (Johnson, 2018). But to adopt camera options such as the Arlo Go or the Spypoint for such purpose, the park would face both technical challenges and licensing issues.

The ease of cellular connection and solar power makes the Spypoint a desirable camera for outdoor usage. However, the Spypoint camera transmits data through pre-purchased data plans, while securing the images in its own cloud server and remote app. Such practice could be a means for protecting proprietary technology involved in the network. We experienced a similar conundrum when working with the Arlo Go security camera earlier in the project. As a result, the app cannot be configured, and the recorded content cannot be accessed without the cloud server designated by these companies. Under these circumstances, the content would have to be manually downloaded before uploading to the park's website. Some form of third-party service may be required to setup an automatic monitoring and reporting system. Such a model not only requires further complex development, but also raises legal concerns for the WSD. Considering the cyber safety risk involved in implementing a private external service, the WSD would rather work around any non-government-friendly terms of service options (Johnson, 2018).

To avoid the complication above, it is ideal to minimize the amount of external service or software required. One alternative approach is to build a camera with a self-established cloud server. To set up such a network, WSD suggested that a File Transfer Protocol (FTP) server can be implemented via a Raspberry Pi (RPi) computer. FTP allows for easy transfer of files between a client and a server (Kozierok, 2005). An FTP server can be set up on RPi with built-in commands to eliminate the need for external service (Raspberry Pi Foundation, 2018). If the connection was established, WSD would be able to access the images on RPi and upload them directly to the park's website.

The Raspberry Pi is a mini computer. To capture images, a camera module can be installed to the motherboard. Compared to Arlo Go and Spypoint, the RPi camera is more economical. With additional accessories such as the cellular module and the waterproof case, the total cost is estimated to be around $150. Since the device is fully programmable, analysis software could be implemented locally. However, due to our team's lack of programming skills, we could only produce some preliminary code to operate the camera module.

For long-term implementation, the program must be suitable for situations in which the RPi camera could operate indefinitely with little to no maintenance. Currently, our RPi camera is capable of taking pictures 24/7 with a specified delay. Our code aimed to minimize the need to manually replace the content storage unit. To prevent the SD card from exceeding its storage limit, older images are erased when a certain number of new images are generated. The same process repeats continuously until the program is manually terminated. A Python file (Appendix B) was set up to demonstrate the intended function.

The average size of the images captured by the camera module is around three megabits. If the camera captures images in five-minute intervals, the camera would generate approximately three hundred images in twenty-four hours, or roughly 0.9 gigabyte. With a standard 32-GB micro SD card, we could store nearly a month of traffic data locally for playback and analysis.

While exploring camera options with Jay Elhard, we were introduced to Michael McCormack from SebecTec LLC. McCormack has built several solar and cellular cameras with the MINISFORUM Z83-F PC, a portable computer similar to Raspberry Pi. In addition, he develops software that help operate the IP cameras. Similar to the approach recommended by Acadia WSD, McCormack's software captures and uploads the images via FTP, which enables direct updates to the park's website. A future team working on this project could reach out to Michael McCormack for assistance on FTP.

Conclusion

Acadia National Park is in need of a more efficient way to monitor traffic congestion. Overcrowding could lead to unpleasant visitor experience, safety hazards, and damage to the ecosystem. The webcam team has evaluated the feasibility of implementing a webcam system for traffic monitoring in the park. To study the feasibility of webcams, the Spypoint Link-S was selected and tested in fourteen locations across the park. Relevant data were recorded, such as the camera's battery performance, cell signal and picture quality.

After weeks of testing, we determined that a webcam could be a reliable tool to remotely monitor traffic in parking lots. Cell signal and the amount of light for solar panels are the limiting factors in determining if webcams can be used in a specific location. For that reason, we recommended the Spypoint Link-Evo which can also take time-lapse photos and upload them to a cloud server. Compared to the Link-S, this model offers a more robust solution with the aid of accessories such as an external 12-volt battery, camera pole, larger solar panel, internal lithium battery, and the range boosting antenna.

The National Park Service can benefit greatly from monitoring visitor traffic via webcams, especially in parks with heavy visitor volume such as Acadia. Overall, we hope that implementing webcams will lighten the workload of rangers and lead to a more efficient flow of visitor traffic.

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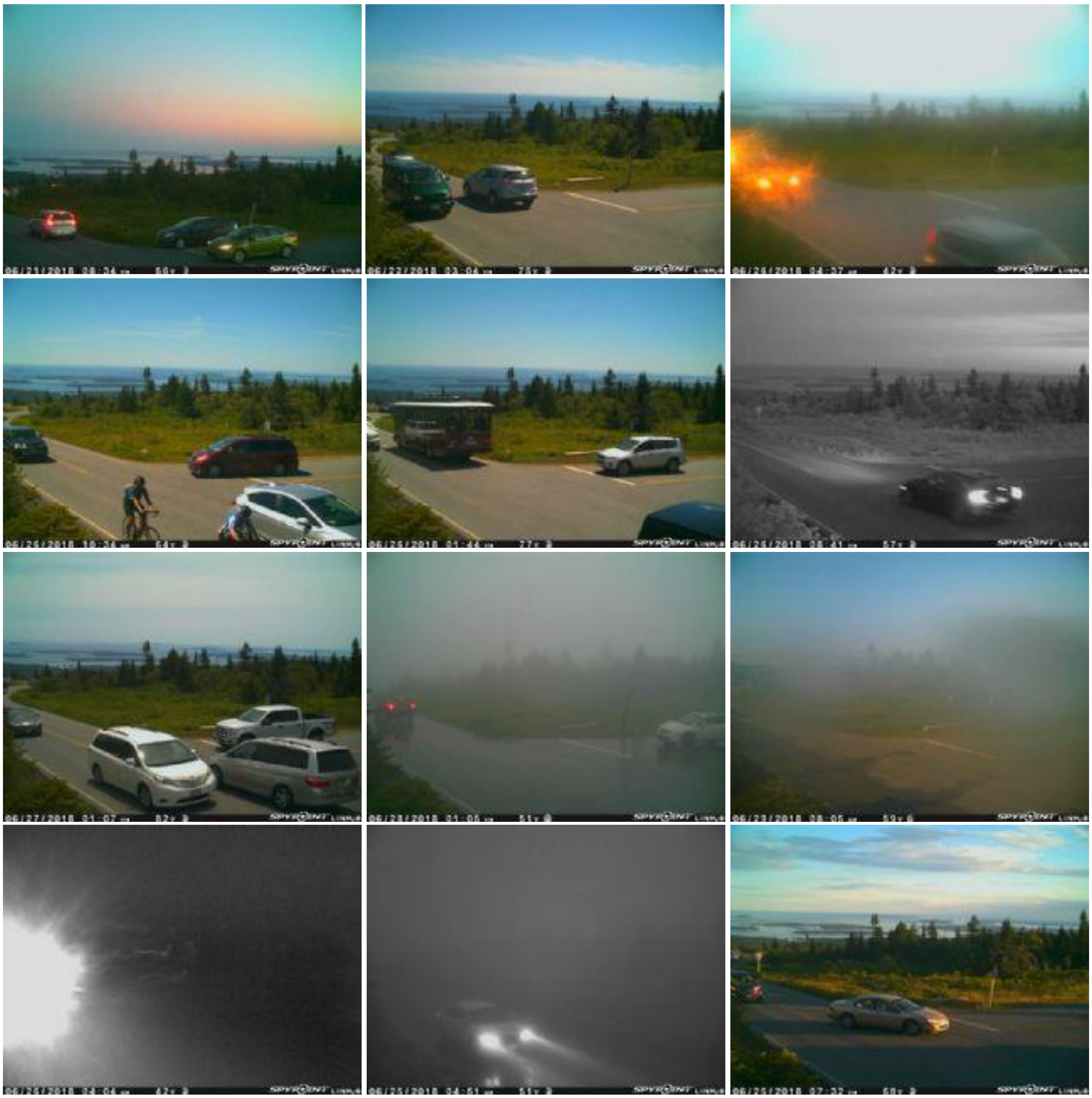
Appendices

Appendix A: Sample Spypoint Photos

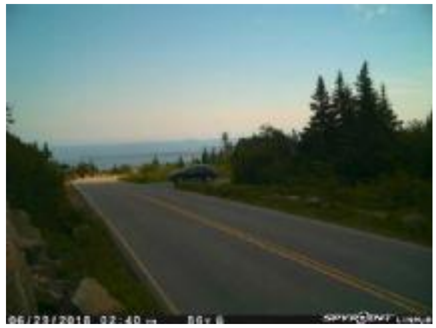
Cadillac Mountain

June 21, 2018 - June 29, 2018



Cadillac Mountain (cont.)

June 21, 2018 - June 29, 2018


Jordan Pond

June 30, 2018



Sand Beach

July 3, 2018



Bubble Rock

July 9, 2018

Jordan Pond

July 9, 2018

Sand Beach

July 11, 2018

Thunder Hole

July 11, 2018

Otter Cliffs

July 11, 2018

Otter Point

July 11, 2018

Mill Field

July 13, 2018

Gilley Field

July 13, 2018

Beech Mountain

July 13, 2018

Beech Mountain (cont.)

July 13, 2018



Bass Harbor Head Lighthouse

July 16, 2018



Hull's Cove Visitor Center

July 16, 2018



Acadia Mountain

July 16, 2018

Echo Lake Beach

July 16, 2018

Appendix B: Raspberry Pi Camera Demo

```python
#This demo captures 3 pictures in 1min at 0min, 0.5min, 1min

import os, time
from picamera import PiCamera
from time import sleep

camera = PiCamera()
camera.rotation = 180

numOfImage = 0
name = 1

delay = 0.5 #capture every 0.5 min
recordTime = 1 #record for 1 min
totalNum = (recordTime/delay) + 1 #total of 3 pic

while numOfImage <= totalNum:
    if numOfImage == 0:
        camera.capture('image'+ str(name) + '.jpg')

    elif numOfImage == totalNum:
        sleep(delay*60 - 1.5)
        numOfImage = 0
        name = 1
        camera.capture('image'+ str(name) + '.jpg')

    else:
        sleep(delay*60) #sleep function is in second
        camera.capture('image'+ str(name) + '.jpg')

    name += 1
    numOfImage += 1
```