# 360 Webcams for Zoos and Aquariums

## Project Plan

**Version: 1.0.0 – 2018.02.11**

## General Information

**Team Number:** sddec18-12

**Client:** *True 360* (Christopher James → chris906@iastate.edu)

**Faculty Advisor:** Dr. Henry Duwe (duwe@iastate.edu)

**Team Email:** sddec18-12@iastate.edu

**Team Website:** sddec18-12.sd.ece.iastate.edu

**Team Members and Roles:**

| Name | Primary Role | Secondary Role(s) |
|---|---|---|
| Nathan Cool | Front-End Engineer | Project Manager, Webmaster |
| Zach Newton | Front-End Engineer | Scrum Master, QA |
| Ian Jamieson | Back-End Engineer | Graphics Lead |
| Alan Negrete | Back-End/Database Engineer | Scribe, QA |
| Tarek (TJ) Yacoub | Embedded Engineer | Communication Lead, QA |
| Hosam (Sam) Abdeltawab | Embedded Engineer | Software Architect |

# Table of Contents

## List of Figures



## List of Tables



## List of Definitions

N/A – Stay tuned.

## List of Symbols

N/A – Stay tuned.

# 1 - Introduction

## 1.01 - Acknowledgements

We would like to acknowledge our client, Chris James, and our faculty advisor, Dr. Henry Duwe, for their contributions to our project. Chris has allocated approximately $20,000 and contributed multiple 360° webcams and other hardware components for our team to use during development. He has also dedicated significant time to meet with us every week as we continue to work out the details of the project. Dr. Duwe has contributed his time and technical advice to our team, as well as assisted in steering us in the right direction on multiple occasions.

## 1.02 - Purpose, Problems, and Solutions

360 Webcams for Zoos and Aquariums is the brainchild project of Christopher James, founder of the Ames, Iowa-based startup company, True 360. The purpose of the project is to provide zoos and aquariums with an easy-to-use 360° webcam system for educational, animal health, and business/marketing purposes.

As of now, there are three problems which True 360 hopes to solve with its 360° webcam project. The first problem is that zoos and aquariums do not have access to an easy-to-use 360° webcam solution for their exhibits. While there *are* zoos and aquariums that currently use webcams (even 360° webcams) for various purposes, no solution currently exists which would allow them to connect and control all of their webcams from a central (remote) location. The second problem is that zoos and aquariums are always looking for ways to boost their web and social media marketing techniques to both attract new visitors and improve public awareness of issues such as animal health and wildlife conservation. The third and final problem is that zookeepers, animal health professionals, and other staff members are currently required to visit each exhibit on a regular basis in order to monitor the animals. This process is time consuming, which means staff members have less time to focus on other responsibilities.

With the 360 Webcams for Zoos and Aquariums project, our team—in collaboration with True 360—aims to provide solutions to these problems. By developing a system which will allow zoo and aquarium staff members to connect and remotely control multiple 360° webcams, the necessity of physically interacting with each webcam will be removed. The system will allow for webcams to be installed in both above-ground (indoor and outdoor) and underwater exhibits and controlled via a central web application. Conveniently, this application will help us solve the aforementioned marketing/awareness and animal health problems. Our system will enable zoos and aquariums to constantly capture 360° footage of animals in their exhibits, which can then be used for educational live streams, creating promotional content for their websites and/or social media accounts, monitoring animal health and behavior, and archival purposes.

## 1.03 - Operating Environment

The major physical components of the system include one or more 360° webcams and any central computing hardware necessary for connecting/controlling the webcams and managing the captured footage. In order for the system to maintain a normal operational state, there are many environmental factors which must be taken into account.

Zoos and aquariums will place webcams in a variety of locations, including both above-ground (indoor *and* outdoor) and underwater exhibits. Webcams placed above-ground and outdoors must be able to operate while exposed to the local weather. Webcams placed above-ground and indoors must be able to operate while in glass-covered exhibits or in areas where visitors' devices may tax the network. Exposing electronics to underwater conditions inevitably poses many potential problems which will have to be addressed (e.g., cable exposure, underwater webcam temperature regulation).

Regardless of where webcams are placed, there are many universal environmental factors which must be considered in order to maintain a normal operational state. The webcams must have constant access to ample power, a stable and strong (wired or wireless) Internet connection, and a case to physically protect the webcam unit. Fortunately, our client is in the process of fabricating a case to fit the webcam model used in the system.

One of the most important environmental factors which must be considered is the presence of animals. The webcam unit must be durable enough to withstand the impact and pressure of strikes, bumps, bites, and other animal interactions. Any cables (e.g., power, Ethernet, USB) connected to the webcams must be installed in such a way as to remain out of the sight/reach of the animals.

In addition to the webcams, we must take into consideration the computing/storage hardware and the software (web application) components and their respective environments. Any computers (desktops, servers) used must be stored in a secure indoor and temperature-regulated environment in order to avoid issues such as overheating and unauthorized access. The web application must be developed with digital security in mind.

Overall, these environmental factors represent our basic understanding of and assumptions about how zoos and aquariums will use the system. They do not encapsulate every possible factor, as there will inevitably be some variance between facilities/users.

## 1.04 - Intended Users and Uses

There are three end users we need to account for when developing the system: zoo marketing directors, zoo curators, and zoo IT departments.

**Zoo Marketing Directors**

Zoo marketing directors will be able to embed or publish (to YouTube) 360° live streams of animal exhibits. Marketing teams will receive a weekly portfolio of pictures and timelapses of when the animals were most active.

**Zoo Curators**

Zoo curators will be able to monitor animals without the need to go to the desired exhibit. Moreover, curators will be able to go back in time—since streams will be digitally archived—to learn more about animals' everyday patterns.

**Zoo IT Departments**

Zoo IT departments will be able to remotely control the webcams, as well as manage live streams.

## 1.05 - Assumptions and Limitations

**Assumptions**

- Our product will not be responsible for managing payments or transactions.
- Our product will be responsible for providing:
    - Webcam management
    - User management (multiple user types)

**Limitations**

- Using manufacturer-provided SDKs/APIs for managing the webcam, setting up live streams, etc.
- Webcams may be limited to connection via WiFi or USB.
- Having broadcasting software (OBS) as a middleman limits our ability to control webcams.
- Server storage cost/space and Internet bandwidth at zoos and aquariums may be bottlenecks for collecting high-resolution footage (1080p, 4K, etc.).

## 1.06 - Expected End Product and Other Deliverables

**360° Live Stream Webcam System**

- Estimated Delivery Date: May 2018 (Version 1), December 2018 (Version 2)
- Product Description (OLD): Our team will develop software for a webcam which can stream 360° video. This webcam will be the first of two primary products that we will deliver. The webcam will use an existing 360° webcam in tandem with the software we develop. The webcam will be used to stream live activities occurring in the exhibits.
- Product Description: Our team will select hardware/software components appropriate for developing 360° webcam software. These components will be selected from amongst existing industry products (webcams, servers, protocols, database frameworks, front-end frameworks, etc.).

**Administrative Portal Web Application**

- Estimated Delivery Date: May 2018 (Version 1), December 2018 (Version 2)
- Product Description: Our team will develop a web application which will allow zoo and aquarium staff members to connect and remotely control the various webcams installed throughout the animal exhibits. As a web application, staff members will be able to access it from a variety of desktop, tablet, and mobile platforms.

**Animal Health Monitoring Web Application**

- Estimated Delivery Date: December 2018 (Version 1)
- Product Description: Our team will develop a web application which will allow zoo and aquarium staff members to monitor the health and well-being of animals. It will utilize machine learning to observe normal animal behavior in order to alert staff members of abnormalities.

**Marketing Web Application**

- Estimated Delivery Date: December 2018 (Version 1)
- Product Description: Our team will develop a web application which will allow sponsors to integrate company logos and product advertisements into live streams. The web application will also allow zoo and aquarium marketing staff to extract various pictures and timelapses for marketing purposes.

# 2 - Proposed Approach and Statement of Work

## 2.01 - Functional Requirements

---

**360° Webcams**

- Stream live video in various resolutions.
- Capture photos in various resolutions.

**Storage Solution**

- The system must be able to store past live streams for archival purposes.

**Admin Web Application**

- A user system must be built-in to control access to various functionalities.
- IT staff must be able to control/monitor the webcams.
    - Turn webcams on and off
    - Adjust webcam settings
    - Start/stop live streams
    - Insert delays between capture and live stream
    - Capture photos
    - View webcam health/status properties
- IT staff must be able to view archived live streams.

**Animal Health Web Application**

- This feature will not be addressed until fall 2018.

**Marketing Web Application**

- This feature will not be addressed until fall 2018.
- Marketing staff must be able to integrate logos and other advertising materials into live streams through the web application.
- Sponsors can “rent” allotted times for selected streams to display their logos and other marketing/advertising materials.

## 2.02 - Constraints Considerations

**Constraints**

- Our product must be able to function in environments with varying temperatures.
- Many of the webcam options are not fully developed or do not supply SDKs/APIs for development purposes.
- The system requires significant bandwidth to ensure stable and high-quality live streams.
- Most webcam options require the use of OBS as a middleman, which limits the amount of custom functionality we can implement.

**Non-Functional Requirements**

- Webcams must be able to stream to YouTube at 4K resolution for prolonged periods of time.
- Webcams should be able to archive live streams at 4K resolution.
- The live stream archives should persist for thirty days locally or in the cloud.
- The hardware and software should be both physically and digitally secure.

## 2.03 - Technology Considerations

**360° Webcams**

- Insta360 Pro – The Insta360 Pro is a professional-grade webcam which provides a wide variety of I/O that we could use to stream videos. Moreover, the quality of the stream is superb and the webcam is able to stream continuously for longer intervals than the other two cameras. Unfortunately, the company that makes the Insta360 Pro does not provide an API or an SDK for developers, restricting us to use of the webcam's proprietary application.

- Garmin VIRB 360 – The VIRB is significantly cheaper than the Insta360 Pro; therefore, it is possible to place more webcams in an exhibit at a lower cost. Garmin provides a complete API for the VIRB which works as advertised. Unfortunately, the camera does not have an Ethernet input (for faster streaming) and only has two lenses, which results in noticeable stitching on the live stream. Moreover, it proved to be difficult to publish the live stream to YouTube since the streaming protocols are incompatible.

- Ricoh Theta V – Like the Garmin VIRB, the Theta V is significantly cheaper than the Insta360 Pro. The Theta V provides more control of the camera compared to the VIRB, as it has a REST endpoint as well as MTP protocol that is used to control the camera through USB. Moreover, the camera has two lenses, which results in a noticeable stitching effect on live streams.

**Front-End**

- Open Source Frameworks
  - Pros – Access to pre-build UI components, supported long term
  - Cons – Not as customizable

- Custom Frameworks
  - Pros – Customizable to our liking
  - Cons – More work to build from scratch; we would need to keep up with web conventions to ensure our front-end application adheres to expectations/standards.

**Backend**

- NodeJS
  - Works on a non-blocking I/O model which makes it easy and clean to use.
  - Scalable
  - Can be used to access the new NoSQL technologies such as MongoDB and CouchDB.
  - Has predefined modules for server side development which makes it easier to write function calls on the server.

**Server**

- Cloud Solution
  - Scalable
  - Medium latency
  - Less expensive in the long run (due to elasticity)

- Local Solution
  - Low latency
  - No bandwidth cost
  - More control of zoo content

- NoSQL
  - DynamoDB
  - MongoDB
  - CouchDB
  - Firebase Realtime DB

- Relational DB
  - It's very difficult to create full NoSQL applications. They are often a hybrid, taking advantage of both technologies. Many complex queries are impossible without relations.
    - AWS Relational DB
    - MySQL server installed on EC2, not likely
    - Microsoft Azure RDBS

**Storage**

- Local Storage
  - RAID SSD 4TB Drive
  - SSD Hard Drive
  - RAID 4-6TB HDD Drives
    - Similar transfer speeds to SSD in RAID 0
    - Main difference is access time, but transfer speeds are the priority for large data.

- Cloud Storage
  - AWS
  - Google Cloud Services

## 2.04 - Safety Considerations

---

- Monitoring the system to ensure safe operating temperature and avoid overheating.
- Make sure all wires are installed where animals can not interfere with them.
- Make sure the application is secure and will not be vulnerable from outside attacks.

## 2.05 - Previous Work and Literature

---

There are currently some zoos (see references) that provide live-streaming webcams on their websites. For example, the San Diego Zoo has live streams for some of their exhibits. The main difference is that many of them are low quality webcams and they are not 360°. Moreover, the streams are unstable and often time-out or disconnect. It's worth noting that they also did not utilize the YouTube platform for their streams. Finally, there appears to be no sound coming from the streams, which could be important when analyzing the animal behavior.

## 2.06 - Possible Risks and Risk Management

Potential Risk – A team member is considering dropping the course.
Management – Maintain open communication amongst team members in order to address and resolve any issues/impediments in a supportive manner. In the event that the situation occurs, communicate with course instructors, our faculty advisor, and the team member in order to mitigate any potential impacts on progress.

Potential Risk – The client loses interest in the project or the project is discontinued.
Management – Team members should think about contingency plans and/or alternative projects. In the event that the situation occurs, immediately contact course instructors and our faculty advisor to determine how to proceed.

Potential Risk – A major hardware component is damaged.
Management – Team members should take care to ensure proper storage, transportation, and usage of all hardware component. In the event that the situation occurs, document it immediately and notify the owner of the damaged component in order to determine whether it can be fixed/replaced under warranty or if complete replacement is feasible.

Potential Risk – Members of the team deviate from the project schedule or team productivity decreases.
Management – Ensure that everyone is on task at all times by utilizing our communication and planning tools and procedures (see subsection 2.08). In the event that the situation occurs, call a meeting to discuss the deviation and identify the necessary steps to return to the proper project schedule (and mitigate any potential losses).

Potential Risk – Research efforts are consuming significant time.
Management – Research is inevitably part of the learning process; however, if research efforts are not leading to the desired results, consider reaching out to other members of the team, pulling in an external expert/consultant (a service offered by our client), or reaching out to our faculty advisor or another faculty member for support.

Potential Risk – Sudden changes in requirements (scope creep)
Management – In order to prevent scope creep, the best course of action is to define a concrete set of requirements and obtain written agreement (signatures) from all parties. In doing so, potential instances of scope creep can be mitigated.

## 2.07 - Project Proposed Milestones and Evaluation Criteria

Our project will contain multiple milestones, most of which will consist of successfully implementing major hardware/software functionalities. Below is the current list of proposed milestones, based on our progress thus far:

- Milestone 0 (Pre-Development) – Successfully identify compatible hardware and software components which will allow us to develop the 360° webcam system.
- Milestone 1 – Successfully develop software which provides a basic interface between a 360° webcam and a live (YouTube) stream.
- Milestone 2 – Successfully develop software which allows users to remotely control a webcam.
- Milestone 3 – Successfully develop software which allows for video storage (archiving).
- Milestone 4 – Successfully develop software which allows logos and advertisements to be embedded in a live stream.
- Milestone 5 – Successfully develop software which uses machine learning to observe animal health and behavior.
- Milestone 6 – Successfully develop software which assists in curating potential marketing materials from existing video archives.
- Milestone 7 (Post-Development) – Successfully deploy the system at a zoo/aquarium.

Evaluation of our milestones will consist of internal development-phase (software and hardware) testing, as well as collecting feedback from our client.

Note: *The milestones and evaluation criteria detailed in this subsection are subject to change as we work to solidify our design and development plans.*

## 2.08 - Project Tracking Tools and Procedures

Our team will utilize the following software tools:

- GitLab + Gitlab Issues – Code repository and task tracking system
- Google Drive – Document storage
- Lucidchart – Diagram storage
- Slack – Group communication

Our team will utilize the following procedures:

- A hybrid "Agile" development process:
    - Each group member posts on our *#daily-standups* Slack channel
        - "What did I do yesterday?"
        - "What will  I do today?"
        - "What impediments are in my way?"
    - Two-week sprints with four official meetings
        - The first Monday of a sprint = planning day
        - The first Thursday of a sprint = progress updates
        - The second Monday of a sprint = progress updates
        - The second Thursday of a sprint = present progress and finalize sprint
    - Dedicated scrum master to manage Gitlab tasks
    - Emphasis on quick turnaround for task completion to facilitate client feedback

- Status reports:
    - Tracks weekly progress (past, present, and future) for each team member
    - Tracks weekly hours contributed by each team member
    - Tracks weekly issues/impediments which may arise
    - Uses a consistent, easy-to-follow template
    - Posted on our team's website every week

## 2.09 - Objective of the Task

By the end of project, our team must have the following objectives complete:

- A web application that is capable of sending commands to a desired webcam, these commands include but are not limited to:
    - Starting a stream
    - Stopping a stream
    - Take still pictures
    - Change stream quality, and other related video/image settings.
- The web application should provide the capability of integrating the live stream to youtube.
- A system that transcodes streams from the webcam to a format digestible by youtube and web pages in general.
- Provide a per zoo service to store streams for a desired amount of time to give zoos the ability to go back in time.
- A process that will embed sponsors logos in the live stream.

Other objectives that our team has in mind, and will be implemented depending on the time frame:

- A machine learning service that can identify some animal concerns such as activity.
- Automatically provide marketing assets to the marketing team at each zoo.

## 2.10 - Task Approach

Zoos ideally will have multiple webcams, these webcams will be connected to the same network. These webcams are controllable through the web application, this is possible because most webcams have a REST API.

Our first design approach is a localized architecture, hence having a local transcoding server and a storage solution.

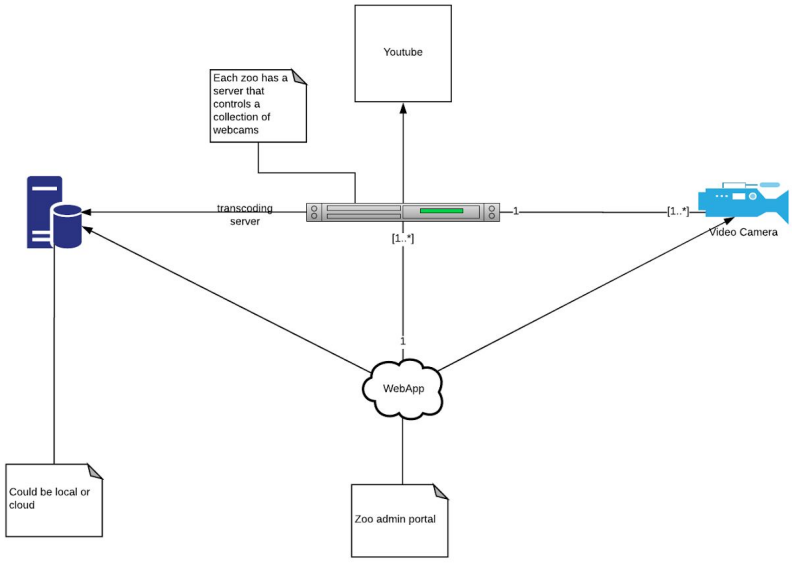


**Figure 1 -** Localized Design Approach

Our second design approach is a cloud based solution, where we could utilize services such as Amazon aws, and google cloud platforms to deploy our transcoding server and cloud storage.

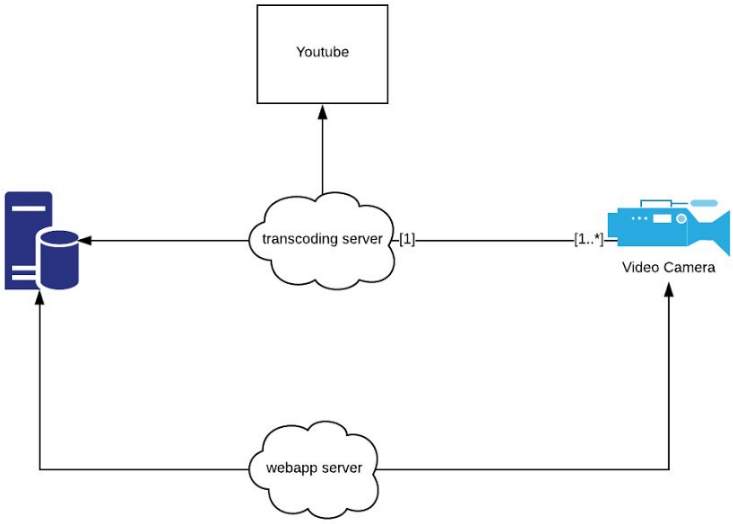


**Figure 2 -** Cloud Design Approach

The functionality is similar in both designs. The purpose of the transcoding server is to digest the video output of the webcams and convert them to a format we could use on youtube, and web pages. Having the transcoding server locally would result in lower latency and no bandwidth costs that are resulted from uploading the videos to a cloud platform. On the other hand the cloud solution is scalable and more future proof. The same applies to the storage solution but is not expected to perform as high of a standard and the transcoding server because it is used to go back through streams when need be.

## 2.11 - Expected Results and Validation

---

Our expected results and validation are closely related to our project milestones. For each of the milestones we expects the following:

- Transcoding Server - The software should accommodate various internet speeds by changing the streaming quality of the webcams. Also the software should be able to handle different streaming protocols in case we have changes in the future.
- Zoo Admin Portal - Webcam should be controllable through the web application with low latency. The connectivity medium of the webcam should not matter.
- Video storage- Be able to archives videos for a desired amount of time. Provide an intuitive way to retrieve videos for a specific timeframe.
- Logo Integration- Logos should be displayed in the right place with not warping effects.
- Marketing App - Provide a place where sponsors can place orders to have the advert shown in future live streams.
- Animal behaviour - Machine learning algorithm should be able to identify some animal behaviour and notify the party responsible.

Note: *The expected results and validations detailed in this subsection are subject to change as we work to solidify our design and development plans.*

# 3 - Estimated Resources and Project Timeline

## 3.01 - Personnel Effort Requirements

| Task ID | Task Description | Task priority | Projected Effort Required |
|---|---|---|---|
| 001 | Decide on a design architecture | High | 4 weeks |
| 002 | Design a transcoding/storage component | High | 2 weeks |
| 003 | Embed logos in live streams | High | 1 week |
| 004 | Design an admin portal (webApp) | High | 2 weeks |
| 005 | Incorporate machine learning | Low | 5+ weeks |
| 006 | Design an upsell platform | Medium | 2 weeks |

**Table 1 -** List of Tasks

## 3.02 - Other Resource Requirements

| Resource Name | Resource Type | Description | Cost | Source |
|---|---|---|---|---|
| Insta360 Pro | Hardware | Professional 4K 360° webcam | ~$4,000 (retail) | Purchased by client. |
| Garmin VIRB 360 | Hardware | Rugged 4K 360° webcam | ~$800 (retail) | Purchased by client. |
| Ricoh Theta V | Hardware | Portable 4K 360° webcam | ~$400 (retail) | Purchased by client. |

**Table 2 -** List of Resources

## 3.03 - Financial Requirements

The financial requirements associated with our project consist of purchasing hardware components and software services.

- Hardware
  - Garmin VIRB 360
  - Ricoh Theta V
  - *Insta360 Pro (purchased prior to the start of our project)*
- Software
  - Amazon Web Services (AWS) or other cloud storage solutions

## 3.04 - Project Timeline

- Project Plan & Design Document
  - This consists of the completion of this document and any other UML design documents that we create for the project.
- Prototype version 1.0
  - At this point, we will begin our Agile Development process. It will consist of daily scrum stand-ups and twice a week in person meetings.
  - We will integrate the Continuous Integration & Continous Development tools provided by GitLab. The prototype will lay down the foundation required for a functionally complete system. The outcome will be all the necessary UI, backend, and hardware functioning to show that the project is feasible and that our approach will work.
  - All external resources (AWS/Server/Database Resources/etc..) will also be part of this prototype to ensure that the main components can communicate with each other and that we don't run into roadblocks later on with choosing the wrong technologies.
- Analyze prototype v1
  - This will part of our in person meetings, we will focus on analyzing the prototype as we go along and fail early. This process will start a week before we develop the prototype, so that we are able to address any minor fixes quickly the last week and perhaps find solutions for the problems. That will save us precious time when we begin development of Prototype version 2.0
- Prototype version 2.0
  - This will be main prototype that we will focus on this semester. The goal for this is to have a solid foundation of our design & a clear understanding of what the feasible solutions will be for the project next semester. It will also help us discard any technologies that will not work and identify any issues with the project design early in the development.
  - The deliverable of this will consist of a fully implemented UI (With placeholders on non-functional requirements). The UI will also have access an a Web API with reliable a realible Wiki for the API. Our API and backend will work completely and connect with any external resources, authentication providers, and with any webcam controls that are functional requirements.
- Analyze prototype v2

- Similar to the previous prototype, analyzing this one will also be something we start doing early, while it's still in development.
- The key outcome of this task is that we will have all the requirements to create our Final Project Plan, Software Architecture diagrams, and any design documents that we will need to begin development of the final product next semester.

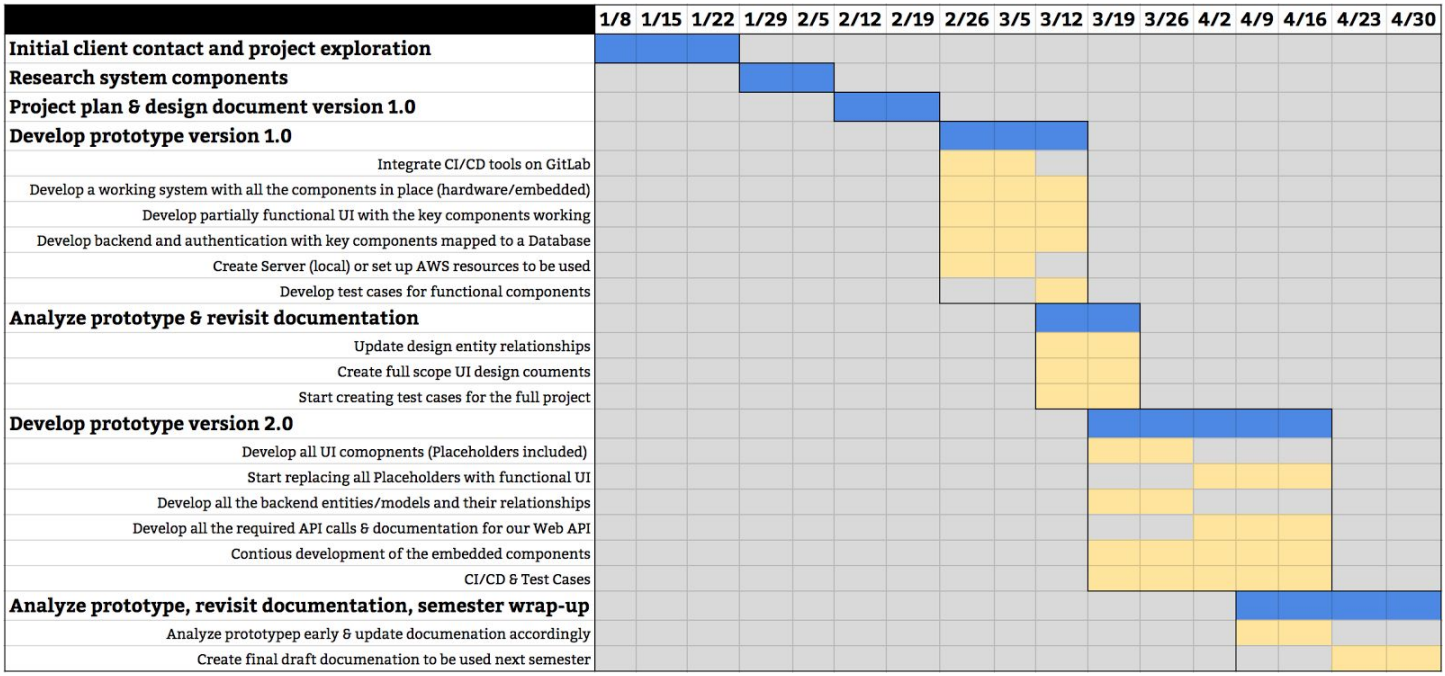


**Figure 3 -** Project Timeline

# 4 - Closing Materials

## 4.01 - Conclusion

In collaboration with True 360, our team aims to provide zoos and aquariums with an easy-to-use 360° webcam system for educational, animal health, and business/marketing purposes. Webcam setups which are currently used by zoos and aquariums provide limited functionality respect to interconnectivity, footage quality, and software features. Our solution will remove the need for physical interaction with each webcam and provide a wide array of software features including centralized webcam control, 360° footage capture/archiving and live streaming, animal health monitoring, and curation of marketing content.

## 4.02 - References

Note: *When academic references are used to assist us in designing and developing our project, we will transition to an official format (MLA or APA) in order to properly cite said references. As of now, this subsection contains bookmarks for the sites we have referred to.*

| Description | Link |
|---|---|
| True 360 (client website) | https://true360.weebly.com/ |
| Insta360 Pro product site | https://www.insta360.com/product/insta360-pro |
| Garmin VIRB 360 product site | https://buy.garmin.com/en-US/US/p/562010 |
| Garmin VIRB developer site | https://developer.garmin.com/ |
| Ricoh Theta V product site | https://theta360.com/en/about/theta/v.html |
| Ricoh Theta V developer site | https://developers.theta360.com/en/ |
| Open Broadcast Software (OBS) | https://obsproject.com/ |
| FFmpeg | https://www.ffmpeg.org/ |
| San Diego Zoo | http://sdzsafaripark.org |

## 4.03 - Appendices

N/A – Stay tuned.

## 4.04 - Changelog

Note: *Changes are listed in descending order (newest on top).*

- **2018.02.11 (Version 1.0.0)** – First draft submitted